HE LAWS OF LIFE

ILLIAM M. GOLDSMITH

shown in the accompanying diagram (Figure 64). In this and similar illustrations it will be noted that ***the less variations from the average*** (represented by the circle, A, Figure 64) ***the greater number of occurrences; and the greater variations from this mean, the less they are found to occur.*** In the words of Gager: "The more any given character departs from the

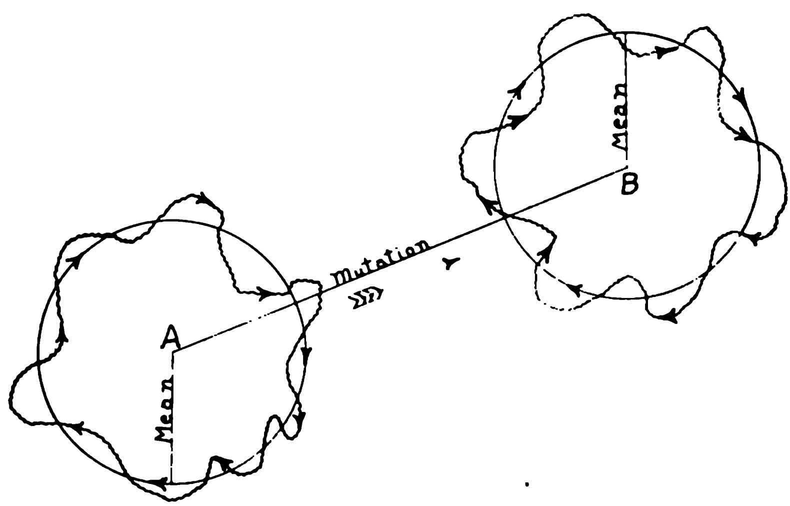

FIG. 64. Diagram illustrating the difference between the fluctuating variation and mutation. The two circles of which A and B are centers represent the average (mean) around which any character may fluctuate, indicated by the irregular lines. Any marked change from this average, as from A to B, is a mutation.

average of that character, the less frequent is its occurrence." This statement of the above considered facts is of sufficient general application to be called a *law*. Having first been suggested (1864) by a Belgian anthropologist named Quételet, (Pronounced Ket-lay), the generalization is spoken of as Quételet's Law.

CHAPTER XIII

MUTATION

Theory of Evolution Based upon Facts of Variation—Darwin's "Origin of Species"—De Vries and the Mutation Theory—Evening Primrose—Examples of Mutations—Polled Herefords—Disease-resisting Cabbage—Purple Beech—Oak-like Walnut—Shirley Poppies—Ancon Sheep—Davenport's Fowls—Strawberries—Roses—Clover—Sunflowers—Seedlessness—Taillessness—Progressive, Regressive, and Degressive Mutations—Causes of Variation—Somatic Variations—Outside Influences—The Cell as a Basis.

"The problem of the exact nature of factor mutations is only a phase of the general problem of the nature of living protoplasm, the solution of which is one of the ultimate aims of biology."

—Babcock and Clausen.

If, in the experiment with the sparrow (See last chapter), the stick which served as a pivot should be moved to some other position (B, Fig. 64), and the swinging continued, the action of the bird would be quite the same—except about a new center. This is suggestive of a discontinuous variation or a *mutation.* Since a well-known theory of evolution has been founded upon the observed facts of mutation, space should be given to a rather detailed consideration of this vital subject.

Altho mutations, *or the sudden appearance of a plant or animal with distinctly new characteristics which breeds true from the start and which fluctuates around its own new standard* (Fig. 64), were never observed as such until within the last few decades, cases of extreme variation had been noted even before Darwin's time. Since slight (fluctuating, continuous, or Darwinian) variations formed the basis for Darwin's theory of evolution, it would be natural to assume that he had the

Changed Environment

Mt. Crested Butte (Colorado) and East River, showing that animal and plant life must be under almost constant readjustment to changed environmental conditions.

A. In Summer.

(See Chapter X.)

THE LAWS OF LIFE

PRINCIPLES OF EVOLUTION,
HEREDITY AND EUGENICS

A Popular Presentation

BY

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DEDICATED

To

the students of Colorado State Normal School and Southwestern College whose keen interest in Evolution, Eugenics and Race Betterment in general has been a constant inspiration to the author.

PREFACE

Emerging half blinded from the mist of the dark ages, man began his untiring search for truth. Slowly but surely he has been freeing himself from the firm grasp of ignorance and superstition. Altho the fire of knowledge, kindled here and there, has spread in various directions, progress in the fields of experimental evolution and heredity have been comparatively slow, biology having been, until recently, largely speculative and descriptive. Investigations into the hidden secrets of Heredity and Eugenics were practically unknown until the close of the nineteenth century. During the first decade of the twentieth century the knowledge which was acquired was largely technical. However, the experimental breedings of innumerable plants and animals have been of inestimable value to the science of heredity. They have laid the foundation for the extensive field of genetics which has since been opened up for the practical workers of the decade just passed. All honor is due these untiring workers, for without their efforts having been made we could not tread to-day with any degree of assurance.

Since 1910, not only have these investigations been continued, but the valuable results of the preceding years have found expression in many excellent books (see literature list at close of this volume), the subject matter of which might well be characterized by the following terms: environment, evolution, heredity, genetics, eugenics and euthenics. Among the thirty or forty valuable and authoritative texts dealing with these subjects, only a few were prepared for the non-technical reader. These books, as a rule, deal with the technical details that are not adapted to the needs of the general public or the students in departments other than Biology. On the other hand, many of the elementary students that receive instruction in the biological sciences fall short of a complete understanding of the general scheme of things. Their trouble is that the attention is focused upon some particular phase, leaving the vision blurred and the image incomplete. Many of the books which may be comprehended by the more informed reader deal with very limited phases of the subject, the material being drawn largely from the authors' own specific fields of investigation. They thus not only become tiresome to the average reader, but also fail to give him a general comprehension of the entire field of heredity and evolution in their true relationships.

The absence of texts for the elementary reader is due, perhaps, to the fact that no writer has ventured to burden the public with the facts of a subject which was changing so rapidly. It has been claimed that such works should be left in the hands of the technical investigators and the amateur who is preparing for this particular line of work. Altho certain changes are still taking place, a sufficient number of dependable facts have been accumulated to be of lasting and practical value. New facts are being constantly brought forward and added to the old. Consequently the center of gravity of the subject is constantly shifting. The fundamental principles, however, must as a matter of necessity remain unaltered. To a certain extent, then, we are sure of our ground. But down to the present, no text has been advanced that covers the entire ground with all the observed truisms.

The master stroke in the way of a general text was struck in 1918 when Babcock and Clausen presented *Genetics in Relation to Agriculture.* Coulter and Coulter's *Plant Genetics* is, likewise, an authoritative text, but emphasizes only those features of the subject that deal with plants. Therefore, it is not truly general in its application, but is limited to a particular line of observation. Both of these splendid treatises are well adapted to the needs of those who intend to make botany, zoölogy, or plant and animal breeding their profession. They are of value, as well, to those who are not as yet specialists but have had training in the fundamentals of the subjects mentioned. The elementary and non-technical reader who desires reliable information on the subject in general must look elsewhere. As the matter stands at the present, such a reader is apt to meet with disappointment. He will find practically all such literature highly specialized and extremely technical. The few exceptions that may be noted are not as wholly general as they might be, and are, thus, not entirely suited to the needs. A broad view of the whole is of more value to the average reader than a narrow understanding of any particular system of details.

The author contends, that the time is at hand when the public is entitled to the valuable information which, up to this time, has been confined to the specialist. The fact that general courses in heredity and evolution are required in many normal schools and colleges is indicative that those in authority realize the importance of these subjects and that they hope ultimately to reach the public at large. Popular prejudice against evolution as a science and heredity as an application is slowly being overcome by the wholesome influence of such instruction. People, as a general rule, are slow to adopt that about which they are uninformed. These courses that are being offered in our schools are going a long way toward broadening the conceptions of the masses.

In the preparation of the present volume, three groups of persons were held constantly in mind. First, it is hoped that the biology teachers in the American high schools will find this an appropriate supplementary text for the consideration of the "Laws of Life." Second, the author's experience in teaching heredity and evolution as a popular course to prospective teachers who possessed but little knowledge of even the fundamentals of biology, should aid in the selection of material for such elementary courses in normal schools and colleges. The demand for such a text is especially urgent in the smaller institutions where the instructor in biology may not be devoting his time to this particular field of the work. In such cases, the text and reference book method, supplemented by lectures, is usually the most successful plan of presentation. Third, it is above all the sincere hope of the author that this work will be of some benefit to the reading public. The time has come when all men are vitally interested in the scientific development of plants and animals, not only from the standpoint of breeding, but also from that of production as well. Sociology has taught us that there is also much to be desired in the betterment of the human family. In order to meet these conditions, a broad and workable knowledge of the elements involved is an imperative necessity. In view of these facts, an elementary consideration of these paramount issues of the day should receive a hearty welcome.

Those who have done some reading in recent books dealing with the subject of heredity and evolution will note that the author has not conformed to the usual method of procedure. He has taken the liberty to develop the subject in a new manner. Several chapters dealing with subjects not generally considered in the texts for students of heredity and evolution have been added. Technical details have been simplified in so far as possible; yet the attempt has been made to retain their individuality and meaning. To an amateur student, such a simplified discussion of the more technical points is very essential to a complete understanding of the problems confronted. Further, a comprehension of the general facts of geological history is indispensable to a thorough knowledge of the successive stages of evolutionary progress. The condition of the earth during the past ages, and how it became "fit" for the abode of plant and animal life, should be understood at least in a general way in order that a more expansive view may be held of the entire process that Nature has executed.

Then, a book having to do with a subject in such a healthy state of growth, as is heredity and evolution, will of necessity carry certain incoherent features, as our knowledge of the facts themselves is more or less incompletely developed. Indeed, the incoherence is of necessity greater because the subjects herein considered are viewed from an elementary standpoint, as technical details that might serve as connecting links cannot be presented. It is hoped that the chapter on "superstition" will suggest to the readers, especially those who are not familiar with the other lines of facts included in this volume, the reluctance with which the intelligent public accepts the "Laws of Life" as ascertained by the world's most painstaking investigators. With a realization of this fact and with a knowledge, tho perhaps superficial, of the basic principles of geologic and biologic evolution, the reader is better prepared to make an intelligent study of practical heredity, genetics, and eugenics.

Altho the following gentlemen are in no wise responsible for the subject matter included in this book, they have presented valuable comments upon certain sections of the manuscript: Dr. J. J. Galloway, Dept. of Geology, Columbia University; Dr. Henry H. Goddard, Bureau of Juvenile Research, Columbus, Ohio; Dr. John C. Johnson, Dean and Professor of Biology, Colorado State Normal School; Rev. J. S. Ferris, Professor of Sociology, Colorado State Normal School, and Warren V. Shepard, Professor of English, Southwestern College. Grateful acknowledgements are also made to many of my former students, especially Mr. C. T. Hurst, as well as to the authors and publishers of numerous books and papers from which material and figures have been selected.

April 1, 1922. W. M. G.

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B. In Winter.
Same scene as frontispiece.
(See Chapter X.)

THE LAWS OF LIFE

CHAPTER I

SUPERSTITION AS A RETARDING FACTOR

An Introductory Consideration

Early Views of Creation—Influence of Aristotle—Imaginative Pliny—1500 Years of Ecclesiastical Influence—Dogmatism of the Dark Ages—Physiologus—Enmity of the Church and Science—Columbus—Copernicus—Alchemy—Witchcraft—Examples of Modern Superstitions—Medical Superstitions—Treatment of Diseases—Interpretation of Birth Marks—Evolution *vs.* Religion—Ideas of Darwin and Milton Compared—Parental Falsehoods—Inheritance of Acquired Characters—Understanding of the Principles of Heredity and Evolution Necessary to the Solution of Many Social Problems.

"Hitherto the development of our race has been unconscious, and we have been allowed no responsibility for its right course. Now in the fulness of time . . . we are treated as children no more, and the conscious fashioning of the human race is given into our hands. Let us put away childish things, stand up with open eyes, and face our responsibilities."

—*Whetham.*

Not more than 150 years ago some of the greatest thinkers of the day believed that during seven "days" the earth was moulded into its present condition, and that the plants and animals, and even men, were fashioned, and have always been practically as they are to-day. Such a supposition, in which progress is disputed and in which it is assumed that the Creator has withdrawn his creative powers, has been one of the serious factors responsible for the retardation of human progress. It is reasonable to presume that the most vital influence that has conspired to bring about these conceptions, and thus retard the advance of civilization, is the mystic cloud of superstition that has been hanging over the human race from the time of the first existence of the most primitive type of intellect. Superstition, at best, is responsible for the dark stains upon the fundamental fabric of human society, and is fostered by gross ignorance and religious fanaticism. It is constantly aiming its blows at the very heart of all that is truly righteous in the march of human progress. It owes its very existence to a false interpretation of Nature and her many moods. Wrong impressions and fanatical ideas very easily degenerate into superstitious notions.

As we study history with reference to the thoughts of men of ancient and medieval times, we are struck with amazement at their dense ignorance of almost naked truths, and we marvel at their fanciful, superstitious ideas. The peoples of past centuries entertained many beliefs and practices which, in this age, would be considered the mark of an unpardonable lack of knowledge, or, more likely, of a questionable degree of mental health. Many of these errors are so apparent that the average grammar school child of today can scarcely imagine that such thoughts ever existed in the minds of civilized men, since the truth is now so evident.

Aristotle (384-322 B. C.), the great Greek philosopher (Fig. 1), was the most noted teacher that the Ancient World produced. In him the philosophical side of Hellenic intellect reached its maximum. For nearly two thousand years, or until the time of Francis Bacon, Aristotle was the recognized authority upon philosophical thought in all its branches. Among his many valuable works, his three books, *Historia Animalium*, *De Partibus*, and *De Generatione* were zoölogical masterpieces for that age. In all probability, some of his biological works that were lost during the Dark Ages were even superior to these. We must therefore give Aristotle the credit for having possessed a knowledge that was both masterful and complete, and, for his time, quite authoritative. But, on the other hand, his entertainment of such beliefs as that the brain was bloodless and that the arteries were air vessels carrying air instead of blood, suffices to show that his knowledge, however far-reaching, was based largely upon misconceptions and misdirected observations.

FIG. 1. Aristotle (384-322 B. C.), who, though a master for his day, possessed many misconceptions regarding some of the simple facts of nature. (From Locy's "Biology and Its Makers," by courtesy of Henry Holt and Co.)

The inquiring minds for many centuries were afforded adequate satisfaction by the arguments and explanations advanced by Aristotle. It is not difficult to see how such an unwarranted acceptance of the ancient teachings could easily have given rise to the hotbed of superstition, which, as we observe, flourished during later ages. We cannot conceive the intricate network of falsities that must have been developed as an outgrowth of this system of philosophy. Knowing that our own fairly accurate knowledge of some of the natural phenomena is due to an inquisitive attitude, which is tempered by a reluctance to accept any explanation that does not stand a test for veracity, we can in some measure understand how the ancient and medieval peoples fell into so much error.

The first one thousand years of the Christian Era, an age that was ushered in by the imaginative Pliny (23-79 A. D., Fig. 2), was a period dominated by a crude and fanciful type

Fig. 2. Pliny the Elder (A. D. 23-79) who ushered in the age of imagination. (From Locy.)

of religious influence. It was a time when the minds of the people were centered upon the spiritual, and when the sum total of the ecclesiastical teachings was to the effect that observations into the workings of Nature were nothing more nor less than irreligious curiosity. During the Middle Ages, this feeling that observation of Nature was irreverent became so prevalent that simple things of every-day life were often described from ancient writings rather than from personal experience, actual experimentation being out of the question.

The application of this principle was rigidly observed and practiced. All ideas of original investigation were banished from the thoughts of men, and any attempt at such was regarded as a serious breach of piety. Superstitious thoughts and practices were not only tolerated, but fostered as well. At one time the question arose as to the number of teeth in the mouth of the horse. This all-important query aroused the curiosity of the people and absorbed their attention to such an extent that many extended and heated debates were delivered and published. In these debates, all the arguments were taken from ancient sources. No one seemed to think of the simple fact that a count would have settled the controversy in a moment. The truth of the matter was that no one dared to mention such a thing because of the doctrine of "irreligious curiosity."

Such a state of affairs could have brought about but one inevitable result. All intellectual life became so permeated with dogmatism that any attempt at rationality was looked upon as rank heresy. It is easy to realize how such conditions gave rise to a superstitious tendency. A mind that is open to dogmatism has to go but one step farther in mental stagnation until the realm of black superstition opens before it.

In the age of superstition that followed closely on the heels of this dogmatic application of the erroneous philosophy of the ancient thinkers, there arose a mystical yearning for some type of natural history. This desire found expression in a Sacred Natural History called *Physiologus*. In it, an attempt was made to symbolize every fact and fable with some religious teaching. This work exercised a profound influence upon the thoughts of men for a long time, and has not been without weight in comparatively modern years. The moral lessons which were taught in connection with contorted stories from nature may well be illustrated by the following story of the method of reproduction of the lion. The *Physiologus* teaches us that "The lioness giveth birth to cubs, which remain three days without life. Then cometh the lion, breatheth upon them, and bringeth them to life. . . . Thus it was that Jesus Christ, during three days, was deprived of life. But God the Father raised him gloriously" (White). In view of the scores of such absurd nature stories that abounded in the lore of the past, which were designed to typify sacred facts, and which passed for solemn truths, we need no longer wonder why our forefathers of not so very many generations ago were so deeply steeped in ignorance and superstition. Even Milton, although belonging to the modern period of history, was plainly influenced by medieval teachings. The following immortal lines quoted from *Paradise Lost* give expression to the primitive views regarding the origin and evolution of life:

"The grassy clods now calved; now half appear'd
The tawny lion, pawing to get free
His hinder parts, then springs as broke from bonds,
And rampant shakes his brindled mane; the ounce,
The libbard, and the tiger, as the mole
Rising, the crumbled earth above them threw
In hillocks; the swift stag from under ground
Bore up his branching head; scarce from his mould
Behemoth, biggest born of earth, upheaved
His vastness: fleeced the flocks and bleating rose,
As plants: ambiguous between sea and land
The river horse and scaly crocodile."

Beginning shortly before the close of the first one thousand years of the Christian Era and extending until about the Fifteenth Century, intellectual progress was largely in the hands of the Schoolmen or Scholastics as they were called. At first, the aim of these men was to define broadly every doctrine of Christianity. They did not question the teachings of the Church, but merely sought in their reasoning to establish a sound basis for argument in order that they might counteract skepticism. In the early part of the Thirteenth Century, the whole of Aristotle's philosophy became known to these Schoolmen through Latin translations. Prior to this time it was only his logic that was in their possession. This new acquisition furnished a great impetus to the Christian thinkers, not only along theological lines, but along the lines of physical science as well. The old religious ideas regarding Nature were beginning to be broken down and the study of her phenomena commenced to be carried out by direct personal observation. This change came about very slowly, for the world was loath to accept any policy so radical, without qualifications. Theology was bitterly jealous of science. For a while all scientific thought was held under control by the Church and made subservient to its own ends. Thus was marked the origin of an age-long struggle that has continued with but little abatement until within recent years.

Those men of science who had the courage to carry on their work independently were the subjects of the hottest kind of persecution. It was not until well into the modern period that they succeeded in breaking away from the direct influence of the Church and pursuing their own course. This course, however, has never been an easy one, for theologians have been, until recently, strewing obstacles in the way at every opportunity. Opposition was constantly met with and, as constantly, overcome. The sway of superstition over science was gradually lessened and eventually degenerated so far that its prestige became fairly negligible.

The discovery of the New World in 1492 opened up new fields for European civilization. It diverted thought from petty affairs and went a long way toward the development of those liberalizing factors that have meant much in the emancipation of truth from falsity. The moral courage of Columbus in the face of overwhelming opposition finally bore its fruits. His memorable voyages resulted in triumph for his ideas and shook several of the most firmly rooted of medieval superstitions to their very foundations (Fig. 3). He conclusively proved, by his daring voyages across unknown seas, that the "Sea of Darkness" and its myriads of horrible monsters had no existence outside the realms of imagination. In 1519 Magellan finished the work of demonstrating that the earth is spherical and not flat. The period of exploration and the later period of colonization marked an era of great progress. Men were becoming accustomed to the overthrow of old and established doctrines. There grew up a tendency to cease accepting the old teachings at their face value, and investigators became prone to discount them in the light of observed facts.

FIG. 3. People once held that the earth was square, having "four corners"; consequently they thought that Columbus would fall off the edge if he sailed very far out into the sea of darkness.

The ancient Chaldean Theory, in its essential feature, held that the earth was the center of the universe. While Columbus and others were busy with their maritime expeditions, Nicholas Copernicus (1473-1543) was exploring the heavens and seeking out the true relationships of the various heavenly bodies. He discovered the true relation existing between the planets and the sun in our own solar system. Copernicus is rightly entitled to the distinction of being called the father of modern astronomical science. His theory, founded upon fact and not upon supposition, endowed astronomy with a firm footing. Copernicus had fully matured his theory by the year 1507, but, fearing the charge of heresy, did not publish it until thirty-six years later. When the theory was made public, both Protestants and Catholics severely denounced it as contrary to Scripture and did all in their power to nullify it. As a result of this opposition, it carried practically no weight in scientific thought during the Sixteenth Century. When the telescope of Galileo made further revelations of the truth, its acceptance was so hindered by the objections of the churchmen that it did not come into its own until the Eighteenth Century.[1]

Any real progress in chemistry as a science during the Middle Ages was impeded by the very nature of its aims and the mystification with which it was practiced. Incidentally, however, important discoveries were made that paved the way for the art of the modern chemist. The alchemists believed in the existence of, and were constantly searching for, mysterious agencies that would transmute the baser metals into gold, cure all manner of diseases, and prolong human life indefinitely. The idea of the transmutation of baser metals into gold was founded upon the old system of philosophy referred to earlier in this chapter. According to the alchemistic opinion, all metals possessed such an intrinsic relationship that they could be changed from one into the other by simply shifting their relative proportions of "sulphur" and "mercury," since the nature of any metal depended only upon the amount of the substances that entered into its composition—a suggestion of the transmutations which actually take place in the radio-active substances. The terms, "sulphur" and "mercury," denoted *qualities* and not the *elements* as we know them today. In order to "purify" the baser metals, such as iron, copper, lead, and tin, and thus convert them into silver or gold, it was necessary only to add certain "medicines"; namely, "Magisterium," "Great Elixir," or "Philosopher's Stone."

[1] See Andrew D. White, "The Warfare of Science with Theology."

Although the Philosopher's Stone was purely a mythical substance, many alchemists professed to have handled it. Thorpe, in *History of Chemistry*, says: "It is usually described as a red powder. Paracelsus says that it was like a ruby, transparent and brittle as glass; Berigard de Pisa, that it was of the color of a wild poppy, with a smell of heated sea salt; Von Helmont, that it was like saffron, with the lustre of glass. Helvetius describes it as of the color of sulphur." Other writers claim that it may be of any color—yellow, red, sky-blue, green, or even white. The literature on the subject of the Philosopher's Stone abounds in directions for its manipulation and the amounts to be used in order to bring about the perfect transformation of a base metal into pure gold. However, these accounts, and especially the "recipes," are as mystical as the wonderful stone itself. Is it possible that any chemist, however learned, could solve the following alchemistic riddle which is claimed to have been used by the philosophers of the Fifteen Century, when "the cult of alchemy attained to the dignity of a religion": "To fix quicksilver:—Of several things take 2, 3, and 3, 1; 1 to 3 is 4; 3, 2 and 1. Between 4 and 3 there is 1; 3 from 4 is 1; then 1 and 1, 3 and 4; 1 from 3 is 2. Between 2 and 3 there is 1, between 3 and 2 there is 1. 1, 1, 1, and 1, 2, 2 and 1, 1 and 1 to 2. Then 1 is 1. I have told you all" (Thorpe). Who could possibly understand this formula? The story is told of a learned professor of alchemy who, when one of his students failed to comprehend his directions and asked for information, said that questions could not be permitted, but that perseverance alone could bring wisdom.

The superstitious belief that the baser metals could be changed into gold was not only prevalent among the ignorant masses, but was championed by the greatest philosophers of the day. In order that the Philosopher's Stone might be found, so that their exhausted treasuries could be replenished, at one time nearly all the sovereigns of Europe were patrons of the science of alchemy and contributed liberally to its support. Letters of patent were granted as conscientiously as patents are issued in America to-day. The following are a few of the men who have loaned their illustrious names to dignify this most spurious and superstitious art: Rudolph II of Germany; Frederick I, and Frederick II of Prussia; Christian IV of Denmark; Charles XII of Sweden; Charles VII, and Charles IX of France; Henry VI, and Edward IV of England. Elizabeth Tudor—supporter of the notorious Dr.

Fig. 4. An alchemist's laboratory, according to the painting of Teniers. (From McPherson and Henderson's "Elementary Study of Chemistry," Ginn & Co.)

Dee—also loaned her name and influence, as well as financial aid, to this pseudo-science.

Although the royal class was more interested in the power of the Philosopher's Stone to change base metals into gold, this mythical substance possessed other powers fully as wonderful. "As it ennobled metals, so it freed the heart from evil. It made men wise as Aristotle, sweetened adversity, banished vain glory, ambition, and vicious desires" (Thorpe). This same element, tho spoken of in this case as the Elixir of Life, had also the power of preserving health and prolonging life.

In view of the great services which this substance might render to humanity, it was vital that a thorough search be made for it. Chemical laboratories (Fig. 4) were established throughout Europe in order that it might be made, while explorers searched every continent and sea for a supposed "Fountain of Youth" that contained the "Elixir of Life." The early Spanish explorers, notably Ponce de Leon, searched long and diligently for such a fountain, but for a very obvious reason failed to find it. These ideas of a supernatural agency were peculiar not only to the Middle Ages and the early modern period, but were quite prevalent during other times. Even before the dawn of the Christian Era, the Arabs and other peoples were searching for it. A story is told of an Arab who was sure that he had found the "Elixir of Life" when he, for the first time, tasted an alcoholic liquor. Thus, we have a notable type of the imaginative and mystic speculations and superstitions that absorbed the "intelligent" minds of the past.

During the last quarter of the Seventeenth Century belief in the existence of witches was almost universal in Massachusetts. In Salem alone, nineteen persons were executed for their supposed witchcraft. Other colonies were not entirely free of the mania. Many of the countries of the Old World were the scenes of the condemnation and torture of innumerable unfortunates. In Great Britain thousands of women were put to death for fancied crimes. The parties responsible for these persecutions claimed Scriptural authority for their acts. Most certain it is that the laws of the land supported them. The close of the Seventeenth Century witnessed the last of religious persecutions and punishment for witchcraft in America. People woke up to the fact that such treatment as was accorded the supposed witches was nothing less than a pernicious example of rank injustice. In Great Britain, however, it was not until 1736 that the obsolete laws aimed at such persons were repealed. Belief in the other manifestations of the supernatural did not die out very soon. Cotton Mather's *Wonders of the Invisible World* gives us a very good insight into the character of the period. The old fantastic notions regarding Nature were not yet entirely extinct. As late as 1742 we note a book entitled *Theology of Insects* by Lesser, while only five years prior to this date Swammerdam's complete works were compiled under the significant title of *Biblia Naturae* (Bible of Nature).

With the final divorcement from the State, the Church was divested of its temporal powers and its authority was restricted to its own individual province. Science was then left unhampered by creed and free to fight out its own battles against prejudice and superstition. However, it required many years for a real spirit of investigation to supplant the superficial and "hearsay" information. The absurd nature stories of Jesse, written less than eighty years ago, are splendid examples of the many non-authentic records which have recently been compiled as facts.

After reviewing the situation as revealed by historical facts, we are forced to admit that the great struggle which has been fought for civilization has been one against a semi-ignorant type of superstition which is backed by the mandates of a credulous religious faith. But, the very moment we boast of the liberality of the present generation; boast of our mental independence; boast that we have been extricated from the bonds of ancient necromancy and are free to consider fact, not fancy; history, not mythology; truth, not error; at that moment the mirror of life is held up before us and we see in our thoughts and actions much that has been inherited from the past. Our posterity will perhaps regard us in the same light as we do our own ancestors. Superstition, although not nearly so rife as formerly, is still a shameful blot upon our vaunted enlightenment. Before we may truly call ourselves enlightened, in the widest sense of the word, we must throw off completely all ties of superstition that have been fastened upon us by our childish credulity and the acceptance of the errors of our fathers. *We must seek out the truth of all* *things* and adopt nothing that bears the slightest stigma of mystery and enchantment.

As we are enjoying a pleasant walk thru Nature's great laboratory, we are disturbed by an omen of "ill luck" presented to us in the form of a black cat crossing our path. Should we pass on the opposite side of a tree from our friend, we are bound to fall into the throes of misfortune. Should we by accident hear a hen try to crow, some member of our family will surely die before long. Upon our return to our cottage,

INSERT I. The magic charm of the horse-shoe.

we are liberated from all these bondages of evil by making various magic signs, or by simply walking under the horseshoe which hangs over our door. Nevertheless, the great condemnation hovers over us again should our child bring a garden hoe into the house, raise an umbrella in our room, or spin a chair on one leg. We are, of necessity, again compelled to rout the evil spirits by more mummery. If a piece of work is begun on Friday, it can never be completed. If you make any garment for your friend while she is ill she will surely die. If it rains on Monday there will be three other rainy days during the week. If it rains on the first day of any month there will be fifteen such days before its close. These things, and others fully as absurd, are believed at the present day by many people who have sufficient intelligence to overlook such childish fancies.

A great number of us have been forced by our parents to wear a small bag of asafœtida suspended about our necks to promote general body development, and, perchance, added to this, a piece of lead to prevent nosebleed. There are thousands of men and women in America to-day who are wearing bracelets of copper to ward off rheumatic pains. These bracelets are usually worn on the wrists. One lady in a certain Colorado village, not receiving the expected relief after following the usual method, conceived the idea of wearing one on the ankle, as well as one on the wrist. These bracelets were placed on opposite sides of the body in order that the "current" might pass diagonally from one side to the other.

The practice of planting potatoes and other crops in the dark of the moon instead of seeking out the very best soil conditions is an excellent example of the superstitious ideas that are very materially delaying progress in agricultural science in this, the Twentieth Century.

Far more surprising and even amazing are the notions and superstitions that men have held in the past regarding the curative powers of certain "medicines" (Fig. 5). Dr. John A. Foote in his article, *Medicine Fakes and Fakers of All Ages*, published in the January, 1919, issue of *The National Geographic Magazine*, has given a good résumé of these "fakes." The use of magic cure-alls, nostrums, and universal antidotes is as old as, and perhaps older than, civilization itself. Medicine and magic were closely allied throughout the ancient and medieval periods. The old Greek word *Pharmakon* may be translated either as "magic" or as "drugs." The classic fable of Mithridates the Great, King of Pontus, serves well to illustrate the imaginary powers of universal antidotes. He was reported to have been totally immune from poisons because of a magic potion that he prepared and took

FIG. 5. "It looks like a modiste's cushion, but it really is an M.D.'s graphic advertisement. It demonstrates the number of spots he knows how to puncture you in. A jab with a needle lets out the devil that's kicking up the internal row.

"These practitioners belong to the school of the old Chinese medicine, which by official proclamation, during an epidemic of diphtheria, advised the public to 'Use Women's Toe-Nails, Bamboo Pith and Bedbugs; Grind to a Powder and Sprinkle in the Throat.'" (From the *World Outlook*, August, 1918. By courtesy of *Christian Herald*.)

daily. When he was defeated by his Roman adversaries, and desired to commit suicide, no poison could be found that would bring about the desired result—one of his soldiers had to kill him with a spear. "The idea of a general antidote for poison was a very ancient and very generally accepted belief. Some of us probably remember the 'mad-stones' which not so very long ago were applied to mad-dog bites to 'draw out the poison.' These mad-stones were unquestionably direct descendants of the bezoar stones of ancient days" (Foote). These bezoar stones of antiquity had a great range of uses. They were used as antidotes and applied externally to cure

INSERT II. An ancient Indian custom was beating human teeth for medicine.

many diseases. The most "valuable" of these stones were obtained from the intestines of the Persian wild goat. They were formed as a kind of concretion of the digestive fluids about some small foreign body in the goat's alimentary canal. Among the many other popular remedies, dried mummy may be mentioned. At one time a flourishing trade in Egyptian mummies existed—much to the sorrow of the modern archaeologist.

During the Elizabethan Period, quackery flourished in England and was nourished by a liberal patronage. Many relics of this period survive in the "nostrums" and "patent medicines" that may be found in the British pharmacies today. Although America has been one of the most fertile fields of patent medicine vending, the public is gradually being educated to the uselessness, or worse than uselessness, of doping their systems with drugs of a questionable character. The medical profession, generally, has agreed to prescribe nothing but drugs of known standards and undisputed value. In this way, the habits and customs of many years may be largely counteracted.

Although we consider ourselves a highly intelligent people, some of the thoughtless among us are still superstitious to a degree that is not only absurd and ridiculous, but disgraceful. In 1918, while the author was studying these problems in one of the southern states, a lady of no mean standing in her community informed him of many "infallible cures" that were still observed and practiced in that section of the country. According to her narrative, a sure cure for night sweats is to place a pan of cold water under the bed before retiring. Unusual pains or cramps in the feet and legs may be remedied simply by turning the shoes upside down on the floor. If this treatment should fail, the ankles should be wrapped with eel skin and immediate relief may be expected. Numerous cures are in vogue for rheumatism. One of the most common of these is the application of rattlesnake grease to the affected parts. Should it be impossible to procure this oil, another and perhaps better remedy may be used. Angleworms, commonly known in the South as "fishing worms," are placed in a bottle, set in the sun, and permitted to decay. The oil of putrefaction, which rises to the top, is applied to the aching member under the same directions as given for the rattlesnake oil.

Many of the current stories of fake drugs and quack doctors are familiar to everyone. In response to a reply of the author to an advertisement in one of the large daily papers, a certain party in Idaho gave the following personal information (Dec. 2, 1918): "This oil is guaranteed to be pure rattlesnake oil. It will stop ringing of the ears or head noises after using a few days, and effects a cure in about six weeks."

Since the price of this oil was six dollars an ounce, the patient might at least be content in that he had used the *best.*

We find traces of the old religious influences cropping out in our country in the form of popular superstitious beliefs. Among them may be mentioned the Biblical treatment for certain ailments, notably bleeding. In this treatment the "physician" places his right hand upon the head of the patient and reads or quotes Ezekiel 16-6: "And when I passed by thee, and saw thee polluted in thine own blood, I said unto thee when thou wast in thy blood, Live: yea, I said unto thee when thou wast in thy blood, Live." The author has seen this administered by persons who claimed no ecclesiastical connections whatsoever. The Bible failed to accomplish the desired result in the case of a child whose nose was bleeding profusely, but the "doctor" was not deterred in the least. He said that he knew two other means of stopping the flow of blood. A roll of raw cotton containing the *seeds* was wrapped around one of the child's little fingers. This was also found to be inadequate. As a last resort, in one case, a ball of dirty spider's web from the attic was forced up the nostril and, as a matter of course, the bleeding stopped. A wad of tissue paper or a cork would have accomplished the same end. The learned "doctor" was rather evasive in his answer when this fact was mentioned.

Superstitious beliefs and practices of the character narrated are slowly passing away, *but they are leaving a culture which makes it difficult for the geneticist and the eugenicist to root out the deceptive notions that are prevalent regarding the science of heredity.* This phase of the subject touches upon the technical, and is even more dangerous to human progress than the other, for it is overshadowed by hasty conclusions as well as by serious misconstructions of the principles involved.

While considering modern conceptions of Biblical references in the face of observed facts, one is at first suspicious of a lack of harmony between the two fields. The spirit of cold speculative skepticism, which pervaded the minds of the scientists of earlier days, has been transferred to the masses, and has made rapid inroads upon all classes of society. This mixture of truth and error is applicable to religion as well as to science. It has been said that the Evolutionists are atheists and are not willing to consider Biblical facts. This is not universally true, altho it may be somewhat true in isolated cases. The Evolutionists are even more willing to accept the catechisms than the masses are to accept the established principles of the sciences of heredity and evolution as proved by undeniable facts. The creation story, as told in Genesis, is more plausible to the eugenicist, if viewed in a certain light, than the scientific explanation of birthmarks is to the average mother (see Chapter XXVIII).

After considering the evolutionary development of life from its earliest stages to its present complexity, Darwin expressed his inner feelings thus: "There is a grandeur in this view of life, with its several powers having been originally breathed by the Creator into a few forms or into one; and that, whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been, and are being evolved." Compare this complacent description with Milton's immortal stanza presented previously in this chapter. Would anyone dare to suggest that the latter is a more plausible interpretation of the creation story than the former? Milton's presentation is thoroughly unscientific and fallacious. The height of absurdity is reached when it is claimed that the all-wise Creator completed His work of creation and then placed Himself upon His great throne and played no further part in the workings of Nature.

A vivid picture of a certain young man who was reared under the old school of religious faith presents itself. When a small child, the Santa Claus story was taught to him as a fact. After a few years his street friends informed him that the story was false. They pointed out the impossibility of a dozen reindeer coming down the chimney and also how improbable it was that one man could take presents to all the children in the world in the space of one night. A little later, when he became inquisitive as to his own origin, he was told that a great stork came one stormy night and dropped him

Fig. 6. Parental falsities. Why should we live in a world of realities and teach only the fanciful?

into the bed with his mother. Later, crude stories from the street established this as another great parental falsehood. He was further impressed with the idea that rabbits laid Easter eggs. Throughout his tender years he was taught, in school as well as at home, that the world was ruled by fairies and sprites rather than by real men and women. All manner of tales of goblins, gnomes, witches, and ghosts were told him by his teachers and his parents. Many American primary teachers pride themselves in stating that such instruction is excellent "food for imagination." Perhaps so, but it occurs to the author that there is more than sufficient detail in such work as Nature Study, for instance, to supply all the "food for imagination" that is desired. Such instruction based upon fact would, without doubt, prove of more lasting value and would not leave so many things to be unlearned. Why should we live in this land of realities and teach only the fanciful (Fig. 6)?

All this time the parents had been teaching their boy about an unknown and indeed imperceptible character called Jesus Christ. What effect would the other stories have upon the reception of this, the only one with any semblance of the truth? When the boy lost faith in Santa Claus, the fairies, and the truthfulness of his own parents, he would be likely to lose his faith in Christ. Mythical customs and false modesty are responsible for far more of the infidelity of this world than is the truth as taught by the science of evolution.

In connection with other Bible lessons, this boy was taught that all plants and animals were created at one time and that Noah took two of every living thing into the ark at the time of the flood and remained for months upon the waters. As he was an inquisitive youth, be began to compute the size of a boat that would be required to accommodate nearly a million individual living forms; he was told by his teacher that there had been described some six hundred thousand distinct kinds of animals and almost as many plants.

While in high school, this young man began to read of the mammoth elephants, the great snake-like animals which weighed thirty or forty tons, and thousands of others which have disappeared from the face of the earth. He sometimes wondered if Noah had representatives of each of these types in the ark along with the present species. If so, the ark must have been considerably larger than some of the smaller states in the American Union. Such a thing was highly improbable to a young mind that was yearning for perceivable facts.

However, he did not allow himself to become prejudiced but waited until some substantial evidence to the contrary should be presented. When he entered upon his scientific work at a university and learned something of the facts of heredity and evolution, he was made to smile at the childish inclinations of the Christian's creed; for, in the course of his own experimental work he observed new forms of plants and animals making their appearance for the first time. If we shut our eyes to the positive facts of evolution, our faith in the creation story and the story of Noah is nothing less than the blind crediting of a glaring mistake. Evolution could, in a measure, explain new types and forms, but *all creation at one time* completely refutes them.

The young man readily concluded that since his own observations proved to him that the animal story was as spurious as the myths that were taught him during his childhood, the story of Jesus Christ must likewise fall into the same category. Thus it is with hundreds of men whose early training was based upon error. The only hope in future years is to overthrow Twentieth Century superstition, Twentieth Century dogmatism, and the Twentieth Century adherence to mythology by a study of scientific facts. Evolution is a science that deals with facts and nothing but facts. *Evolution does not deny the existence of a Supreme Being, but it does grate harshly against the grain of some present-day interpretations of certain Scriptural passages.*

Among the many other advantages to be gained from a study of the modern problems of heredity and evolution, an understanding of the relation which exists between heredity and environment seems very important. This is a subject about which there are many and varied ideas. Most of the people seem to hold the opinion that characters acquired by the parents are transmitted to the offspring. One of the arguments used by many lecturers against the use of intoxicating drinks is that the desire *acquired* by the father may be handed down to his *children*. A study of the elements of heredity and eugenics will suggest a more accurate explanation for this perplexing question.

It is the custom of many charitable institutions to collect the street waifs, regardless of their low heritage, clean them up, and, after caring for them a few months, place them in the best of homes where they mingle with children of superior birth. Their theory is that environment will overshadow all hereditary taints. The true answer to such a supposition can be found only thru a close study of eugenics and euthenics. A mixed family of white and black children was pointed out to the author while he was visiting the slums of a certain city. The mother of this brood was said to have been a most vile prostitute and to have never been married. Those poor children, no doubt, had inherited the lowest strains of physical, mental, and moral constitutions. If some respectable family should be so unfortunate as to have the germ plasm of these illegitimates mixed with their own pure line, many wrecked homes could be pictured as the result of the matings of such unequal young people, altho they might be placed in an identical environment. We can never hope for the solution of such vital social problems until the principles of heredity, eugenics, and euthenics are better understood by everyone that is in the slightest degree concerned.

As yet, the science of heredity has not penetrated so very far into the unknown, but it is treading on firm ground, and its attainment of certain ultimate goals is only a matter of time and patience. The time element depends, to a certain extent, upon the attitude of the masses. The subject of plant, animal, and human development should be of sufficient general interest to be discussed at large and taught in our schools. However, the public is loath to discard its old ways and accept new facts, even tho these facts may be well established. Lyell said that it took almost 150 years to get even the learned men to believe that bones, teeth, and shells found in the earth were the remains of real animals, and another 150 years to persuade them that such remains were not "freaks of nature" or the remains of the animals that perished during the Mosaic Deluge. If the people of the present age are as slow to accept the recently compiled facts of evolution, heredity, and eugenics —many of which are more startling than the above—progress along these lines will continue to be extremely slow.

CHAPTER II

CONSIDERATION OF TERMS

Evolution—Current Conception *vs.* Fact—Mechanical Evolution—Geologic Evolution—Biologic Evolution—Heredity—Genetics—Eugenics and Euthenics—Importance of Extending the Subject—The International Congress of Eugenics—Attitude of American Teachers—Our Responsibilities.

"In biology all roads lead to evolution."

—Conklin, '20.

"With regard to the* fact *of evolution there are now no dissenters among thinking people."

—Shull, '20.

Evolution

The term "evolution" has been employed so carelessly that one scarcely knows what shade of meaning is implied when the word is used. However, to many, it suggests a type of human development as related to the lower animals, especially the monkeys. This fact was illustrated when a few years ago it was the author's privilege to offer the first course in Heredity and Evolution in a certain denominational college. The first day, without any preparation or preliminaries, every student was requested to write his own definition of evolution. Twelve out of a class of only thirty wrote the following: "Evolution is the theory that man came from monkey." Other definitions that were written conveyed the same idea. When we realize that a large proportion of the common people, and indeed many men and women of college standing, have no broader view of this subject than to consider it a study of the parallelisms between man and monkey, we do not wonder at the lack of interest that is being shown in its several lines of development.

Before considering the meaning of evolution, it may be well to emphasize the fact that it "*neither eliminates God, nor does it teach that monkeys are the ancestors of man.*"

Many of those who have a more accurate impression of evolution will state that it refers to the development of higher forms of life from simpler forms. It is not necessary, however, to restrict the meaning to the plant and animal kingdoms. As looked upon from a broader aspect, "*evolution is an attempt to explain the present conditions of the world in terms of simpler preëxisting conditions*" (Castle). In other words, evolution is the theory that the various types of organic life have gradually developed from other simpler preexisting types, and that the inorganic world has in like manner come to its present state of complexity thru a continuous process of change. From this viewpoint, then, evolution refers to the process which all nature has undergone thruout the past ages; it unrolls the scroll of the past, and puts the key to the situation in our possession. In brief, it treats of the progressive changes which have taken place in both the organic and inorganic world thru the course of time. "To insist, as some have done, that the theory of evolution has failed because it has not yet solved all of these problems is to underestimate both the magnitude of the problems concerned and the progress which has been made toward their solution; to reject evolution, as others have done, because the problems are too great to be solved by the scientific method, is to renounce the slow and sure progress of science in favor of pure speculation and mysticism in which no progress at all is possible."—Conklin.

In order that a broad and clear understanding of the term under consideration may be gained, it is well to apply it not only to the works of Nature but also to the works of man. In this regard, the whole subject may be divided into three separate and distinct subdivisions; namely, (1) Mechanical

Evolution, (2) Geologic or Inorganic Evolution, and (3) Biologic or Organic Evolution.

Mechanical Evolution.—The remarkable results that have been attained by man as a product of his skill and inventive genius have been the consequence of a long and tedious evolutionary progress. All that has been accomplished in every line of endeavor exhibits the marks of having undergone such changes in the course of their fashioning. We are reminded, while considering the remarkable perfection now reached in the purification of metals as well as in their uses, that countless ages ago some primitive man must have found, by accident, molten metal on his crude hearth. He later noted that this metal could be moulded into crude tools and weapons with which to prepare his food and to battle against his enemies. As ages passed and the minds of men became more highly developed, primitive methods for the extraction and purification of metals were discovered and gradually introduced. This paved the way for a more specialized and a more durable type of weapons and implements. New and important discoveries that often had a direct bearing upon existing things were occasionally brought forward. In the case of weapons, for instance, not so many centuries ago, it was found that even the most perfectly constructed swords and daggers were inadequate. Upon the introduction of gunpowder, different and more powerful weapons were required and devised in order to keep pace with the times. At first, these, too, were extremely crude, as an examination of the relics of former wars will show. However, by the addition of parts, piece by piece, from the skilled hands of many generations, the modern instruments of warfare have become a reality. Thus, starting with a piece of molten metal in the fire of the savage, the process of mechanical evolution of weapons has proceeded to the production of the modern long range guns which startled even the military experts during the World War by sending death-dealing projectiles into the heart of Paris from a distance of about seventy miles.

Elias Howe has generally been given the credit for inventing the sewing machine, but investigations prove that it came through a series of evolutionary stages. Records seem to indicate that the first sewing machine was made by Thomas Saint in 1790. It was a very crude machine, made of wood. Instead of having an eye, the needle had a small notch. It was necessary to punch a hole in the material being sewed in order that the needle and thread might pass through. Bartholemy Thimonier (1830) invented a machine in France which proved so successful that it was used by the French government to make clothing for the army. His first machine was constructed of wood, but later he made one of steel. Thimonier's machine did very slow work because the needle had to be passed back and forth twice to complete a stitch. In 1841, Newton and Archbold improved this machine by inventing a pointed needle with an eye which produced the lock stitch. It was not until 1846 that Howe patented his machine, which was simply a combination of previous features. This machine of Howe's was further improved in 1849 and 1854 by John Bachelder. In 1851, Isaac Singer effected many improvements, such as the vertical needle, the foot treadle, and the presser foot. The evolution of the sewing machine has proceeded at such a rapid pace that now it is possible to embroider, make buttonholes, hemstitch, shirr, tuck, darn, gather, and produce various other varieties of sewing by mechanical means. By this example we find that the modern sewing machine did not spring spontaneously from the brain of one man, but that it was brought from a very simple and crude beginning to its present complex and improved form. There is no question but that this process of mechanical evolution will continue until we have a much more perfect machine than we have to-day.

The evolution of the printing press and the art of printing is a story that is familiar to every student of history. Our modern presses that are capable of turning out thousands of complete newspapers in an hour are worthy descendants of the slow and clumsy presses of Gutenberg and Franklin. Applied electricity is a field of science and mechanics that had its humble beginning hundreds of years ago when man first began to play with "statics" as a curious toy of no practical value. The most graphic illustration of progress is shown when we study the evolution of man's methods of transportation. The United States leads the world with regard to mileage of railroads. Less than a century ago there was not a single mile of railroad track in the entire country. Railroad equipment has more than kept up with the increase in mileage. Our modern trains with all their appliances to insure comfort, safety, and efficiency, are indeed many steps removed from the first

Fig. 7. An early railroad train, from which has gradually been evolved the mammoth locomotive of to-day.

"coach" drawn by Peter Cooper's diminutive locomotive that made the trip from Baltimore to Ellicott's Mills in 1830 (Fig. 7).

The best example of mechanical evolution along the line of methods of travel may be found in a study of the history of the steamboat. Regardless of the fact that history teaches us that Robert Fulton invented the steamboat in 1803, we find that over two hundred and fifty years before Fulton's time, a Spanish captain, Blasco de Garay, was reputed to have built a steamboat of his own contrivance. The next we hear of this kind of navigation is when Jonathan Hulls (1736) took out a patent for a towboat which was propelled by steam power. Many trials were made after this, but none were successful in any degree until 1782 when the Marquis de Jouffroy d'Arbans constructed a steamboat and navigated the Saone River. In

1786, Fitch and Rumsey constructed a paddle steamboat, but this was a failure because the boiler burst. After this, they lost enthusiasm. When Fulton built the "Clermont," as its period of success outlasted those of the other steamboats, he received all the honor for the invention. However, the steamboat had previously been quite successful and had passed thru a state of evolution of many years' duration. Man in the present day has so evolved his modes of travel that he no longer must confine his journeys to the surface of the land and the sea. He can navigate over the one with aëroplanes and dirigibles, and under the other with submarines. It should be quite conclusive from the above illustrations that evolution is active in the mechanical world. It is also possible to show that the same developmental principles are equally as effective in the geologic world.

Geologic Evolution.—A study of the early formation of the earth and the tracing of the rising of the continents as carried out in geology are really problems of evolution. In like manner we often speak of the evolution of the stars and of the solar system. The term evolution, then, applies with equal force to the making of the universe in its entirety, as well as to its component parts. Since this phase of evolution is so far reaching, special chapters are reserved for a consideration of it. In this way it will be more convenient to consider the entire process of the preparation of the earth for the abode of life.

Biologic Evolution.—The noted discoveries in the field of geology led naturally to the extension of the doctrine of evolution to the biological sciences. Evolution, as used in this more or less restricted sense, is usually spoken of as biologic or organic evolution. When looked at from this angle, the following definitions are quite applicable:

"The theory of organic evolution relates to the history of animal and plant life. Evolution is the development of an organism; the gradual growth and unfolding of its parts and organs."

"The evolution of an organism means its descent from preceding organisms with continuous adaptation to its environment."

"Evolution is the history of the steps by which an organism has acquired the characters which distinguish it." Babcock and Clausen give a somewhat similar but more technical definition: "Evolution is the general name for the history of the steps by which any living being has derived the morphological and physiological characters which distinguish it."

As biologic evolution implies a general relationship between all life, a comprehension of this profound subject cannot be gained until viewed from a broader aspect. (See Chapters VII, VIII, and IX.)

Meaning of Heredity

If we examine the characteristics peculiar to our family, we find that we are moulded like our parents in many respects. If one of our parents is irritable and inclined to be high tempered, we will likely possess the same characteristics. This relationship which exists between successive generations and which produces this resemblance is called *heredity*. It will be shown later that both mental and moral traits are inherited. A father who is a *natural* musician may transmit this desirable quality to his child. The son of a man who possesses an *inherent* desire for intoxicating liquors will be much more likely to become a drunkard than the son of a man who does not possess such a desire. *Heredity, then, is the transference to offspring of the parental characteristics.* It will be noted that this applies to the very common characteristics as well as to those which are very exceptional. Too often we look upon heredity as something mystical, and, indeed, applicable only in rare instances. The facts that a robin's egg hatches a robin instead of a sparrow; that a boy "sprouts" a beard; that a dog's body is covered with hair; that a child can speak; and, that the mountain lion is ferocious are all examples of heredity. In truth, any physical traits which are characteristic of a species may be considered under the subject of heredity as appropriately as if they were family traits such as hereditary eye and hair color. These simple facts of heredity have been observed for over two thousand years, but the significant and practical application of them has been delayed until since the opening of the Twentieth Century. Plato ". . . warned his countrymen of the degradations in store for any nation which perpetuated the unfit by allowing its citizens to breed from enervated stock, and he sketched for them an imaginary republic in which no consideration of family ties or of pity, were permitted to stand in the way of the elimination of the weak and the perfection of the race" (Warner). Herbert Spencer and others have presented an early word of warning regarding the danger of the prevalent custom of shielding people from their hereditary sins and defects. It will be shown in later chapters that the warning which was sounded by the early workers is now being heeded and that their advice is in general quite sound.

Regardless of the fact that these, and many other writers, both early and recent, have optimistically viewed the improvement of the race thru the application of the laws of eugenics and euthenics, it is quite surprising to find others who contend that there has been little improvement of the human race thru inheritance. Hayes in his *Study of Sociology* says, "But there now appears to be no scientific basis for the idea that the present rich complexity of human endowment will ever be materially exceeded. Neither is there any reason for supposing that the Chinaman of to-day is materially better born than was Confucius, or the Greek of to-day better born than were Aristotle and Pericles, or the Hebrew of to-day better born than were Moses and Abraham, or the Egyptian of to-day better born than were the builders of the pyramids, or the Mesopotamian of to-day better born than were the architects of the hanging gardens of Babylon, or the Germans and Americans of to-day better born than Germanicus, Agricola, and Caractacus, or the general population of half-naked savages that at the dawn of European history roamed thru northern forests." If the above is true in its most restricted sense, the laws of species formation, which are so generally applicable to all plants and animals, certainly do not apply to man—

FIG. 8. A Sixteenth Century nose.

"The nose, rough in outline and broad at the top, was common to Nordics in the sixteenth century, and by no means rare in the seventeenth. Here the upper eyelid is more like a modern, but the eye is by no means as deep set as is usual to-day. The portrait is that of Nathaniel Byfield, 1653-1733." This suggests that man is still undergoing evolutionary changes. (From *Journal of Heredity* (after Bolton), article by Frederick Adams Woods.)

which supposition is not substantiated by scientific investigations. Although much credit must be given to social evolution and the improvement of the human race thru the change in environmental conditions, it seems too far-fetched to place the hereditary standing of our enlightened race upon a par with the "half-naked savages" of the dawn age. Especially does this seem absurd when we are reminded that many physical changes have been wrought in man since that early time (see Chapter IV, also Fig. 8). If man has changed so materially in his physical make-up, why should he not likewise have changed in mental characteristics as well?

Genetics

Genetics is almost equivalent to the term heredity. In fact, Shull, '20, says it is "the science of heredity, variation, sex determination, and related phenomena," and Conklin, '20, says that it "deals with the inherited characteristics of successive generations of individuals." From a technical standpoint, genetics is a much broader term than heredity. It includes both heredity and environment. It is the study of the production, differentiation, and transformation of organisms. Such a broad consideration would involve all agencies both outside and inside the organism that may either directly or indirectly affect it. Professor Castle states that: "Genetics is the science which deals with the coming into being of organisms." Herbert E. Walter gives us another clear conception of genetics in his statement of the geneticist's task: "To unravel the golden thread of inheritance which has bound us all together in the past, as well as to learn how to weave upon the loom of the future, not only those old patterns in plants and animals and men which have already proven worth while, but also to create new organic designs of an excellence hitherto impossible or undreamed of, is the inspiring task before the geneticist to-day."

Eugenics and Euthenics

If genetics deals with all factors which have to do with the betterment of the race of any given line of organisms, whether plants or animals, then *eugenics and euthenics combined constitute the genetics of man;* the former referring to man's heredity and the latter to the improvement of the human race thru environment. According to Galton: "Eugenics is the science of being well born"; in other words "it is the study of agencies under social control that may improve or impair the racial qualities of future generations either physically or mentally." It is readily seen that this science deals entirely with the improvement of the human race by selecting better hereditary qualities with which to begin life. The destiny of the individuals now living is sealed, as it is impossible for us to be reborn under more favorable conditions. Eugenics, then, is designed only for the future generations.

Eugenist or Eugenicist?

"With the development of the science of eugenics, two practically interchangeable words have come into use for indicating a person who studies eugenics. These words are 'eugenist' and 'eugenicist.' The present practice, however, seems to be to discard the term 'eugenist' in favor of the term 'eugenicist.' This preference is desirable because it is based upon sound etymological grounds. Literally, the word 'eugenist' means one who is well born, while the word 'eugenicist' means one who is versed in the science of eugenics. The syllable '-ic' or '-ics' in the latter term means 'the science of,' which meaning is entirely lacking in the shorter word. From the standpoint of euphony, the shorter word possibly has a small preference in its favor. But this shortness and euphony are clearly overbalanced by the correct etymological content of the longer word. In the official correspondence of the Eugenics Research Association, and in the editorial policy of the EUGENICAL NEWS, therefore, the term 'eugenicist' will, in the future, be used to the exclusion of the term 'eugenist,' to mean a person who is concerned with, or versed in, the science of eugenics." Feb., '22.

The Development of Eugenics

Ten years ago the subject of eugenics was practically unknown in America. The American people were too much absorbed in the commercial improvement of plants and domestic animals to think of the betterment of their own race. A drive for practical eugenics, however, was inaugurated in 1908 when the American Breeders Association appointed a eugenics committee composed of David Starr Jordan, Luther Burbank, Bell, Castle, and others. From this time onward the improvement of the human race has been a supreme question in the minds of American thinkers. The workers from such an organization as the American Genetics Association (publishers of *The Journal of Heredity*), the Carnegie Institute, the Rockefeller Foundation, the National Committee for Mental Hygiene, the American Social Hygiene Association, and the American Federation for Sex-Hygiene are stimulating an interest in eugenics as well as in other practical lines of heredity and euthenics. The founding of the Eugenics Record Office at Cold Spring Harbor, Long Island, by Mrs. E. H. Harriman has stimulated much interest in family records. Popular interests are now so aroused in this new science that every section of the country is welcoming conferences, exhibits, press articles, as well as open discussions from the pulpit and in the Sunday Schools. Normal schools, colleges, and universities all over the country are introducing courses in heredity, eugenics, and euthenics, while many of the biology teachers in the American high schools are embodying eugenic principles in their regular courses. Two great international congresses have been held; the first in London in August, 1912, under the auspices of the Eugenics Education Society, and the second in New York City in September, 1921. "Since that first notable meeting in London, the World War has come and gone and the question in more than one country is whether the finest racial stocks have not been so depleted by it that they are in danger of extinction, for more than any other this war has been destructive of the best. The war has left the economic, sociologic, and biologic conditions of the world greatly disturbed. Never before has the need of international coöperation and enlightenment been felt so keenly." The Second International Eugenics

Congress therefore came at a time of exceptional interest, when the need for some systematic methods of race improvement was felt by millions of thinking people throughout the earth.

A study of family histories has revealed the fact that various physical, mental, and moral discrepancies are handed down from generation to generation and thus that radical social restrictions on hereditary influences are needed. Drastic measures for the prevention of social disease transmissions alone, are great factors in race preservation and improvement. A number of states have not only passed stringent marriage laws, but have caused to be put into effect many other precautionary measures.

In face of the fact that the American teachers are aware of the social consequences of uncontrolled hereditary influences, they continue to ignore the urgent demand to present a digest of the subject to their students. "It is amusing but sad to realize that our schools have expected the pupils to know the location of small islands in the South Pacific Ocean, the height of a mountain in Asia, the population of Honolulu, how many men fell in the battle of Marathon, to learn by heart 'The Charge of the Light Brigade' and 'Thanatopsis,' translate and scan Virgil, memorize verses of the New Testament in Greek, and find the value of 'pi' in geometry, but not a word about eugenics. It is impossible to believe the ignorance of natural physiological laws which many of our children exhibit at the time of graduation from our high schools and colleges. The average mother has failed to teach her daughters important truths, because she thought it was too delicate a subject to discuss with them." Rhodes, in his excellent book, *The Next Generation*, concludes the chapter on Eugenics thus: "A report of the Eugenic Section of the American Breeders' Association says: 'It is a pressing problem to know what do to increase the birth rate of the superior stocks and p down, proportionally at least, the contribution of the erior stocks. Another great need is the simplification of standards of living, for it is the inordinate desire for display that makes many persons hesitate and begrudge the expense of children.'

"A prominent eugenicist has recently said: 'The fact of the matter, which eugenics hopes to mitigate, is social, and its roots lie in social causes. It can be cured only by social remedies. Bracing up an individual here and there does not help; more are cast down in a day than are picked up in a year. Bringing about an occasional 'eugenic marriage' only serves the immediate individuals, and serves them only until they learn that artificial mating without love brings no more social health than when a king mates his daughter to a neighboring prince for political reasons.

" 'Eugenics proposes its body of scientific facts as a vehicle for its social measures. We are all to blame for these anti-eugenic things. There is a child condemned from birth to epilepsy or syphilis because of its father's sin; but we all helped and permitted that father to sin by neglecting to do our job in eliminating the brothel or the saloon. There is a brood of feeble-minded children born to misery and to be a social cancer; we are to blame in not demanding that the parents be segregated before they became parents—segregated as tho they had smallpox. There is a mother bringing a succession of under-nourished children into the world to be prostitutes and criminals; we are to blame for the slum where that mother grew and for the sweatshop where she played out her vitality before she married in desperation to escape it, or in the passion which was the natural result of her untrained parental instinct.' "

"The thought of evolution now dominates *all* sciences—physical, biological, physiological and sociological."

"It is manifest that sociology must depend upon biology, since biology is the general science of life, and human society is but part of the world of life."—Sociology and Modern Social Problems.

—Ellwood.

CHAPTER III

SOME INTERESTING THEORIES

Introduction—Early Speculations as to the Structure of the Universe—Greek Ideas—More Recent Views—Our Source of Knowledge of the History of the Earth—Study of the Solar System—Growth of the Earth—Bombardment by Meteorites—Compression—Atmosphere and Water—Inorganic Synthesis—Formation of Water and the Oceans—Appearance of Life—Origin of Life—Creation Theory—Origin of Cosmic Dust—Origin by Inorganic Synthesis—Absurd Ideas—Spontaneous Generation.

"*A fire-mist and a planet,*
A crystal and a cell,
A jelly-fish and a saurian,
And caves where the cave-men dwell;
Then a sense of law and beauty
A face turned from the clod,—
Some call it Evolution,
And others call it God."

—*W. H. Carruth.*

Introduction

To perceive the rapid changes of nature at the present time, it is essential to investigate those of the past. If it is clearly seen that the earth has undergone evolutionary and at times seemingly revolutionary transformations, the present-day changes will be made much more obvious. When an impression of contemporaneous evolutionary agencies is obtained, it is then, and only then, that a perception can be gained of man's opportunity to direct the trend of affairs to his own advantage. It is here that the practical side of evolution comes into play. Furthermore, it should be evident that these LAWS OF LIFE which are to-day being summoned to man's service have been operative thru all the geologic ages. A study of the progressions which have taken place from the beginning of time is, therefore, the basis of a knowledge of factors which are influencing plant and animal life to-day, and which are moulding the destiny of the human race. Such an inquiry may advantageously be extended back into the dim precincts of hypothesis. The origin of the earth and the origin of life itself may be speculated upon with profit. From this mist of hypothesis, step by step, we have passed down the ages in which geologic facts have given us an accurate conception of the actual conditions which existed, and thence, we follow the laws of progress into the present age which might fittingly be called the "Practical."

The Origin and Evolution of the Earth

Many and varied have been the notions entertained in the past regarding the shape and extent of the universe in general. Prior to the discovery of America, medieval men held the belief that the world was smaller than it really is and that it was in the form of a disc.

Babylon was responsible for the formation and the promulgation of the doctrine that the blue heaven was a solid, vaulted dome and that the stars were eternal fires supported in the substance of its structure. The earth was surrounded by a sea, and beyond the sea lay a mighty range of mountains upon which rested the superstructure of the vaulted heavens. The sun sped on its course in a vast arch under this dome by day, and returned to the east at night by a subterranean passage. Such were the ideas taught by the ancient Babylonian and Chaldean astronomers. Chaldea passed thru her five thousand years of existence without hitting upon any vestige of truth of the vastness of the universe. Egypt borrowed her astronomical science from Babylon. Some peoples, like the Hebrews and the Persians, who came under the influence of the Babylonian culture, refined these ideas of the universe with new additions of their own. But everywhere, the earth was shut in by the solid vault of heaven. These ideas persisted even as late as the latter part of the Middle Ages, when telescopes of the pioneers of modern astronomy began to peer into the mysteries of the unknown and to seek out the true state of affairs.

Ancient Greece, in her brightest days, developed some thinkers who introduced many new ideas that were remarkable for their nearness to the truth. Among these men may be mentioned Pythagoras, who taught that the earth was a sphere and that it revolved on its axis once in twenty-four hours. He, however, still clung to the notion of a material heaven. He thought of it as a hollow sphere revolving with myriads of stars around a central fire. The earth also revolved around this central fire of which the sun was a mere reflection. Pythagoras had but a small following and his ideas soon fell into disrepute.

With the decay of the Greek nation there came a diminishing in the force of its culture. The teachings of the rational thinkers were rejected for the time being. Greek culture was transferred to Alexandria where it came into contact with the culture of the East. A heroic attempt was being made to gather tangible material regarding the system of the universe when the Dark Ages settled down over the earth like a vast, covering mantle, shutting out the guiding light in advance of knowledge.

Remarkable as were the speculations of men of former times concerning the physical features of the universe, even more remarkable were their deductions regarding its origin. From the very dawn of history we find authentic records of this spirit of theoretical inquiry. Each noted people of antiquity has left behind some record of its thoughts along such lines. Mythology, as handed down from generation to generation, has carried the tale even farther into the dim prehistoric past. The ancient Greek priests explained that the heavens and the earth were formed from the body of a disreputable goddess. Her body had been split asunder. From one half, the god of light constructed the earth; and from the other half, he raised the vaulted dome of heaven. Another teaching was that the firmament was a goddess arched over the earth on her hands and feet, being forced by some successful adversary to assume and hold that position eternally. The Greeks had many different accounts of the beginning of the world. Homer tells us that a mighty flood, enveloping the land and sea like a serpent with its tail in its mouth, was the prelude of all. Other myths say that darkness was the first condition of nature.

Democritus, a Greek of daring inspiration, approached the truth when he taught that the universe was composed of an innumerable host of minute particles which he called "atoms," and that they gradually settled into their massed forms from a chaotic state of confusion. His teachings, like those of Pythagoras and others, were cast aside as rubbish and buried beneath the debris of mythology during the Dark Ages.

There were also many different traditions regarding the origin of man himself. The Greeks did not settle this question as easily as did the Hebrews. Some said that both gods and men were derived from "Mother Earth," others, that they were produced by the rivers or the sea, or that they grew out of trees and rocks.

This character of conjecture was uppermost in the minds of men until after the Dark Ages. In the early days of the Christian Era, however, a certain impetus was given to *systematic* thought along these lines. But all philosophical efforts were retarded during the decline and fall of the Roman Empire, and no further progress was made until after the Fifteenth Century. This lack of scientific investigation into the origin of the earth and the origin of man was caused by the religious sentiments which were uppermost in the minds of the men of that time.

Even as late as the Eighteenth Century the geologists continued to be baffled over the significance of various layers of rocks which constitute the outer crust of the earth and contain fossils which show a succession of life. They seemed to have thought that numerous life cataclysms had taken place. It was assumed that in each case all living forms had been obliterated and then, following such universal destructions, re-creation had taken place. In each successive creation the new forms were assumed to be a higher type of life than the pre-existing forms. Such assumptions would account for the presence of the lower forms of life in the lower rock strata and the higher life near the surface.

However, the later geologists have studied the diverse layers of rock which constitute the outer crust of the earth and are able to read its history far back into the ages of geologic time. In the main, the upper layers carry a complete record so unmistakable that the geologists are enabled to read as from an open book. The lower layers are so distorted that little information can be obtained from them. Still lower the rocks are entirely inaccessible, and thus cannot be made to reveal any historical facts. The knowledge of the outer surface of the earth blends with the hypothesis of the interior. Even tho geologists, by studying the rock layers, have been able to construct a fairly accurate history of the evolution of the earth during the past few million years, they have been unable to find any definite data which would seem to point to the phenomenon of its origin. Here they are by necessity forced to speculate. They must form the hypothesis to fit the observed facts, or find facts to fit partially predetermined hypotheses. Should new observations, however, necessitate the framing of another hypothesis, the old one might be of great aid. The truth often lies midway.

The Origin of the Solar System, Including the Earth

Many theories have been proposed to cover the origin of the solar system, and, more especially, the earth. Since they possess many elements in common, a general consideration will given rather than a detailed discussion of each theory. Before an attempt is made to gain an understanding of the methods of stellar evolution, it is very necessary that the reader should conceive, insofar as possible, the stupendousness of the universe. However, the inter-stellar distances are so great that the human mind is incapable of grasping their *true* proportions. We have no system of measurement that will represent them in anything but almost meaningless numbers.

As we marvel at the beauty of the milky way, little do we realize that the astronomers with their enormous telescopes of utmost delicate adjustment, together with their sensitive plates, have actually recorded over a hundred million stars in its path. Although our own sun has a diameter 865,000 miles and is 93,000,000 miles distant from the earth, thousands of stars in the milky way are hundreds of millions, or even trillions of miles farther from the earth than is the sun. When we gaze upon the many stars of the heavens that are visible to the unaided eye, we are unable to distinguish any marked differences in them other than differences in their apparent size and brilliancy. The astronomers tell us that the spectroscope reveals the fact that they differ remarkably in temperature and structure. There are thousands of shining bodies in the heavens, which the spectroscope shows to be nothing more than collections of thin shining gas. These peculiar masses of incandescent gas are called *nebulae* (Fig. 9). There are only two nebulae that can be observed with the unaided eye, namely, the middle "star" in the sword of Orion (the big hunter), and the nebula in the constellation of Andromeda. Moulton speaks of Orion as "the most wonderful and beautiful object in the heavens." He estimates its mass as 100,000,000,000,000 times that of the sun. When examined in detail, a nebula is seen to be made up of a central shining mass called the nucleus from which are given off two or more radiating arms twisted into the form of a spiral. These arms contain aggregations of luminous masses of a "knotty" appearance. Throughout the entire nebula there seems to be a fleecy cloud-like consistency with here and there a hazy nucleus. The general appearance of a nebula, as a whole, is highly suggestive of a common toy fire wheel.

While many "stars" seem to be in this nebulous or gaseous

Fig. 9. A spiral nebula. Photographed by Ritchey. (From Schuchert, by courtesy of John Wiley and Sons.)

state, others seem to be partly condensed into a solid, and still others are seen to be in advanced stages of solidification, while little, if any gaseous matter is present. With these observations as a basis, certain workers have suggested that these conditions represent different evolutionary stages in the development of a star.

Beginning with a gas of inconceivable tenuity, we are able to follow the successive steps in the development of a star through its several evolutionary stages until it passes into a solid planet such as the earth. However, according to the planetesimal hypothesis as set forth by Chamberlin and Moulton, "the remote ancestor of the solar system was a more or less condensed and well-defined central sun, having slow rotation, surrounded by a vast swarm of somewhat irregularly scattered secondary bodies, or planetesimals (little planets) which all revolved in elliptical orbits about the central mass in the same general direction.

"According to the planetesimal hypothesis, our present sun developed from the central parent mass, and possibly some outlying parts which fell in upon it because they had small motions of translations. The revolving scattered material contained nuclei of various dimensions which, in their motions about the central sun, swept up the remaining scattered material and gradually grew into planets whose masses depend upon the original masses of the nuclei and the amount of matter in the regions through which they passed."

Moulton clearly pictures the origin of the planets thus:— "The parent of the solar system consisted of a central sun surrounded by a vast swarm of planetesimals which moved approximately in the same plane in essentially independent elliptic orbits. Among these planetesimals there were nuclei, or local centers of condensation, which, in their revolutions, swept up the smaller planetesimals and grew into planets."

It will be noticed that according to this conception the central nucleus of one of these nebulae laid the foundation for our present sun, and that the various planets which revolve around the sun were formed from the nebular knots of varying sizes.

Although it is quite presumptuous to speculate upon the fate of the stars, it might be suggested that astronomers are quite agreed that after a certain stage in the cooling process the stars are no longer self-luminous. The temperature gradually diminishes until they become cold and dark.

Such "dead" stars would represent the culmination of the great process of stellar evolution. Since all the bodies of the shining heavens are presumed to be going through such stages, we might conclude that countless millions have been formed and have passed through the period of growth, adolescence, and senescence; thus, dotting the expanse of space with cold, dark bodies. We are not disappointed in our assumption, for the astronomers tell us that the existence of many invisible bodies has been conclusively demonstrated.

Since the cold and dead stars are invisible, man has not been able to study them or even to prove their existence until within recent years. The existence of these invisible stars is best shown by certain eclipses of shining stars. One of the most illustrative examples of this peculiar stellar behavior has been recorded by Lowell. This is a certain star amid the polar constellations known as Algol—El Ghoul, or "The Demon" as the Arabs called it. The name shows that they observed how it winked its eye. Lowell speaks of it in his *Evolution of Worlds* thus: "For once in two days and twenty hours its light fades to one-third of its usual amount, remains thus for about twenty minutes, and then slowly regains its brightness." Its loss of light is occasioned by a dark companion, of about its own size, passing in front of it while revolving about it in a close elliptic orbit.

It might be presumed that these "old" stars continue moving in space until some great calamity befalls them. When it is known that millions of shining stars, and probably billions of "dead" ones, are shooting through the heavens with an average velocity of about one and a half million miles per day, we are not surprised to note that many astronomers consider collision one of the culminating processes of stellar evolution. "If two stars should collide, the energy of their motion would largely be changed into heat, and the combined mass would be transformed into a gaseous nebula" (Moulton). Thus, the life cycle of any heavenly body would be expressed: Nebula, very bright and hot stars (losing heat very rapidly), cool and dim stars, cold and dark bodies, collision, intense heat, nebular dust (Fig. 9).

The Evolution of the Earth

Regardless of the specific method of planet formation, it seems conclusive that the earth was at one time in its infancy, and that conditions were not favorable for the abode of any form of life as we now know it. The small meteorites or planetesimals continued to bombard the earth until it became a globe of approximately the present diameter. This constant bombardment probably was one of the factors which caused an increase in temperature of the earth. The bombardment theory, to account for the heating of the earth, may well be illustrated by shooting a large number of bullets at a steel target. If the bombardment is kept up sufficiently long, the rise in the temperature of the target becomes very noticeable. However, such factors as self-compression caused by the enormous pull of gravity, and the liberation of subatomic energy in uranium, radium, and other elements, might have been more important in the production of heat than the factor just considered. This heat, however it might have been produced, became so intense that the rocks in the interior of the earth were reduced to a liquid. When the outer crust of the earth began to cool and solidify, the inner molten mass, because of being under very heavy pressure, perhaps burst through at certain points in violent volcanic action. Our modern volcanoes are usually explained as a more gentle continuation of this same action.

Origin of Water and Atmosphere

In the age of violent volcanic action, vast amounts of volcanic gases from the vaporized rocks passed into the surrounding space, the temperature was reduced, and, as they became cooler, there was a tendency for them to again combine with each other. This recombination is synthesis. However, since they are under new conditions, they will unite in new and entirely different combinations. The formation of water is an example of inorganic synthesis with which every student of chemistry is familiar. If oxygen and hydrogen are mixed, and should this collection of uncombined gases pass over the volcano in eruption, an explosion would take place in which the two gases would be chemically united into the compound of H_2O—containing two parts of hydrogen and one part of oxygen. By certain other chemical and physical recombinations or synthetic processes, the various gases of the atmosphere probably came into existence.

The early bombardment was naturally greater at certain points, and thus the earth's surface was left uneven. The newly formed water accumulated in these depressions. The shrinkage of the earth's crust and the internal pressure caused it to bulge and warp, thereby adding another cause to the many changes that the beds of the primitive oceans have undergone. The rising of the continents and the upheaving of the mountains were brought about largely by the same forces. Volcanic action, too, played a large part.

With the formation of the atmosphere and the water, conditions became quite favorable for life, perhaps before the earth was fully matured. Indications show that life appeared long before the earth was full-grown, and while the average temperature was quite high—perhaps over 150 degrees Fahrenheit. For a long time it was considered impossible for life to exist at such a high temperature. Certain algae, fungi and bacteria have been observed in recent years to be able to live in water at a temperature of about 180 degrees Fahrenheit. No form of animal life within the knowledge of science could exist under such conditions. This suggested that plant life was the first to come into existence, since animal protoplasm has far less resistance to heat than has plant tissue. Chamberlin considers that animal life made its appearance upon the earth when the average temperature was probably 115 degrees Fahrenheit.

There are two other factors which seem to indicate that plants appeared upon the earth long before animals. First, free oxygen, which is absolutely necessary to the support of animal life, was, for a long time, exceedingly scarce because it was continually being consumed in the synthesis of water, and it has been shown that plant life can exist in an atmosphere containing but little oxygen. Second, present observations clearly show that animals are either directly or indirectly dependent upon plants for food. Thereupon, it is logical, disregarding all other factors, to assume that plants appeared upon the earth before animals in order that food might be prepared for the higher forms of life.

The Origin of Life

"On the basis of established facts of Biology it can be said that we know nothing of a positive nature as to the origin of life. It is the greatest of the unsolved problems confronting man."

—*Schubert.*

Many eminent scientists have held the belief that life was transferred to our earth from some other planet by meteors. From the standpoint of the *origin* of life, this view is wholly inadequate, for it does not give us an inkling of the beginning of the germ of life itself. It merely shifts the origin to another world and leaves it unexplained. Physically, such a transfer would seem impossible. The impact of the meteor would be so great that the heat involved would probably kill any living organism present. The idea of the origin of life that is generally accepted among the masses of people is the story as told in Genesis. Genesis teaches that in the beginning God *created* the heavens and the earth, all plant and all animal life. According to the interpretations of the populace, He snapped all life into full being, full grown, from nothing. Our knowledge of the history of the earth as revealed in its rock strata, and our knowledge of the evolution of the organic world, refute this *interpretation* of "Creation."

Broadly speaking, there is no real conflict between this theory of evolution and the theory of the "Creation." We know that the foundation of the universe rests upon countless billions of minute particles of matter called atoms. These atoms are fundamentally the same in both organic and inorganic matter. Whatever may have been the order of the formation of the universe, the old Greek, Democritus, may have been wholly right when he supposed the primitive state to be a chaotic confusion of these minute particles, and that they slowly settled into orderly arrangements. This cosmic dust strewn broadcast through space and destined to form future worlds, may have possessed within itself all the potentialities for the development of both organic and inorganic matter. This seems to be a plausible view, since the gap between the organic and inorganic chemistry is closing up. They now blend into each other. This brings protoplasm much nearer to the inorganic world and makes the problem much more simple. Since both organic and inorganic matter contain the same basic elements, it is not at all out of place to consider their origin together. Whence was the origin? We must look to the primitive cosmic dust for a solution to our problems. But whence came the Cosmic dust? Ah! no scientist has yet ventured a theory! Is it not probable that herein lies the true province of Divine Creation?

Haeckel has said, "I assume that the first monera (lowest animal) owe their existence to the spontaneous creation out of so-called inorganic combinations, consisting of carbon, hydrogen, oxygen and nitrogen." But whence came these elements? This view is known as inorganic synthesis and is the credited explanation for the origin of life, but it only throws the query back into another realm. During the Archean Age (see next chapter) of geologic time, conditions were perhaps favorable for life to make its appearance and thrive. Environmental conditions, such as temperature and moisture, play a very great part in the chemical action. The same elements unite in entirely different compounds under varying influences. Probably in the Archean Age were formed the first albuminous compounds, whose chemical characteristics are peculiar to the living matter. This process took place by synthesizing carbon, hydrogen, oxygen, nitrogen, etc. Therefore, according to this method, the origin of life may be explained upon practically the same basis as the origin of the atmosphere and the origin of water. It has been claimed by the supporters of the theory of inorganic synthesis that the process did not stop with the formation of protoplasm, but has since been evolved into a great variety of living creatures; but, on the other hand, it is claimed by some that the process of life making has continued even down to the present day, and that it is entirely overshadowed by the forms that are descendant from it. However, Chamberlin suggests that the production of the protoplasm in nature might now be impossible owing to the destructive powers of bacteria. This difficulty would not have been confronted in the early days before bacteria appeared upon the earth. The fact that chemists have on several occasions been able to produce a protoplasm-like substance in the laboratory would seem to lend support to the view that man may some day produce this life substance. However, it must be borne in mind that no substance has been, as yet, produced, which possesses metabolic powers, or which is irritable in a living sense. Emil Fisher has succeeded in producing polypeptids (combination of Amino-acids), and Butler Burke has provided other links between living and non-living matter, but the actual production of living protoplasm in the chemical laboratory is, as yet, a human impossibility. If it should so happen that some synthetic process should be discovered by which active living protoplasm could be made, or even a higher form of life originated, man could not even then be called a creator; he would have become only a discoverer of another method of the Great Creator. Our religious convictions need be shaken no more by a biologist producing life in the laboratory than by the chemist's solving some of the modern problems of electro-chemistry.

Others held that life was the original condition of matter. This seems untenable when we think of the method of the building up of new worlds. Life cannot be associated with such mighty cataclysms as usher them in. In this connection, some may contend that life is without beginning, and is perhaps eternal, as Hutton, Playfair, and Lyell taught in their *Doctrine of Eternity and Uniformity in Geology.* They taught the whole planetary system to be eternal and unchangeable. Lord Kelvin reminds us that Playfair "assumes that the sun is to go on shining forever and the earth is to go on revolving around it forever." From our knowledge of stellar evolution, we consider this to be unsound.

A very absurd view regarding the origin of life is the one known as *spontaneous generation.* Observation without sufficient inquiry into facts is wholly responsible for the rise of this doctrine. When people saw frogs and toads emerge from their hibernating places in the mud, they naturally supposed that the mud was responsible for their spontaneous generation. Decayed flesh was a favorite place for flies to lay their eggs, and thus the notion was brought about that flies were generated from the dead flesh of animals. The possibility of eggs being laid therein was entirely overlooked. During the Middle Ages barnacles were thought to grow on trees, probably because they were found on driftwood. Barnacles were then supposed to change directly into geese; bees were generated from the carcasses of oxen; hair-worms arose from the hairs of horses' tails; insects came from the dew under the influence of the morning sun; worms were produced from the walls of the intestines of humans and of animals. These and many others were typical of the beliefs of that time, and some are current even to-day. The theory of spontaneous generation was completely overthrown by those notable experiments of Redi (1626-1694, Fig. 10), Pasteur (1864), and Tyndall (1876). They proved to the world that life not only came from life, but that *like* produces *like* with but little modification.

After all, we are forced to admit our ignorance regarding the exact origin of life, and to bow in reverence to the Unknown

FIG. 10. Francesco Redi (1626-1697), who overthrew the theory of spontaneous origin of life by simply proving by experiments that maggots hatched from eggs of flies instead of being moulded from decaying meat. (From Locy, by courtesy of Henry Holt & Co.)

Creator of the *elements*. The uncertainties of our theories are shown by Chamberlin's statement (*Science*—June 1899): "Mathematics and dynamics fail us when we contemplate the earth, fitted for life but lifeless, and try to imagine the commencement of life upon it. This certainly did not take place by any action of chemistry, or electricity, or crystalline grouping of molecules under the influence of force, or by any possible kind of fortuitous concourse of atoms. *We must pause, face to face with the mystery and miracle of the creation of living creatures.*"

"Some call it Evolution,—
Others call it God."

CHAPTER IV

MEN AND AGES

Signs of Ancient Life—Fossils—Stratification by Sedimentation—Periods of Earth's History—Archeozoic—Proterozoic—Early Paleozoic—Later Paleozoic—Mesozoic—Cenozoic—Development of Plant and Animal Life during Cenozoic Age—Evolution of Man—The Ape-Man—The Dawn Man—Stone Age—Copper Age—Bronze Age—Iron Age—Coal Age—Electrical Age—Flying Age.

"Thus life by life, and love by love,
We passed thru the cycles strange,
And breath by breath, and death by death,
We followed the chain of change,
'Till there came a time in THE LAW OF LIFE
When over the nursing sod
The shadows broke, and the soul awoke
In a strange, dim dream of God."
—*Langdon Smith.*

The inquisitive eye, aided by the microscope, finds that the stones, from which many of our houses are built, are nothing more than a conglomeration of the remains of microscopic animals, molded together and tightly cemented in a petrified condition (Fig. 11). How strange it is that the remains of these ancient creatures, which could live only in salt water, are found on the plains or on the mountain tops, hundreds of miles from the seashore. Fossil Mountain, in western Colorado, is an instance of such a place in which sea forms are found in abundance 13,000 feet above sea level and over a thousand miles from the nearest coast. These fossil remains are sufficient proof that much of our present land areas were once largely or entirely covered by the sea, and that these waters were inhabited by a strange type of marine plants and animals. The accompanying small maps (Figs. 12 and 13) give an excellent idea of the extent of the North American Continent which was exposed above the level of the sea during

FIG. 11. A typical key which unlocks the mysteries of bygone ages. Note the great variety of animal life entombed in the rock.

those early times, and also of the process of its growth in subsequent ages.

Many forms of plants and animals have been buried and preserved to tell the story of a world that teemed with life, long before man made his appearance. The aquatic animals would, when dead, settle to the bottom and become a part of the rapidly accumulating sediment. The rapidity of sedimentation may be seen by observing the amount of mud laid down in the bottom of a small pond (Fig. 14) during a rainy season. If, within a few weeks, several inches of sediment accumulated upon the floor of the pond, what could be expected to be laid upon the floor of the sea throughout geologic time? It is estimated that within a single year the Mississippi River

Fig. 12 (left). Archean North America, modified from Shailer and others. Black represents land area.

Fig. 13 (right). Cretaceous North America, showing approximate area covered by the great Kansas Seas which formed a belt through the North American Continent.

carries almost 500,000,000 tons of earth and soluble salts into the Gulf of Mexico.

In the simple case of a pond's filling during a rainy season it will be noted that, when the water evaporates, the sediment of the next season will be distinctly separated from that of the first. Thus, one could readily determine by counting layers, or strata, the number of rainy seasons during which sediment had been deposited. In like manner, the different sedimentary strata of the earth's crust, which have become stone, give us valuable facts regarding its past history. A million years come nearer the unit of time than an annual rainy season, when the geologic history of the earth is under consideration. The most common kinds of strata formed by a process of sedimentation are the shales, limestones, and sandstones. It is seen from the above discussion that the crust

Fig. 14. Sedimentary pond (Colorado Rockies) in which various animals and plants of to-day are buried. They will thus be preserved to tell the story of the 20th century life to the future races of men.

of the earth is largely sedimentary rock, and that the layer nearest the surface was the last one formed—the oldest being found the deepest in the earth. In order that the geologists may speak intelligently of the various strata, they have divided the whole space of time into ages or eras. Each era is subdivided into periods.

The oldest systems of rocks in normal position are below all other strata. Various causes such as volcanic action, shrinkage, and pressure may throw them out of their original location or distort them. The most primitive rocks known to geologic science are spoken of as the Archean rocks, and were formed in the Archeozoic Age (Primal Life). The lowest of these rocks were formed by volcanic action during many millions of years when the whole globe was pitted with the most gigantic volcanoes, when the oceans were seething with fiery lava, and when the land surfaces—as we know them—had not yet assumed the slightest resemblance to their present outlines (Fig. 12). Under such conditions one would not expect to find any forms of life upon the earth; and, as a matter of fact, no traces of life are found in the oldest of the Archean rocks.

The Chart of the Ages (Chart I) will give the reader information regarding these more general divisions of geologic time. The duration of each period as well as the facts pertaining to the life of each are approximated from the statements of various workers. The chart is reversed from the customary arrangement in order that a comparison with the scroll of animal life as outlined in the chart (II) accompanying Chapter VII may be facilitated. It will be noted that the successive appearance of the various animals is highly suggestive of the increasing complexity as set forth in the scroll of life. The fact that the oldest rocks, and those deepest in the earth, are charted first should not confuse the reader—indeed, this would seem to be the more natural order.

The term Archean was given to the first age and Proterozoic (Primitive Life) to the second. This terminology was ascribed on the assumption that the former was absolutely devoid of life or any trace of living matter, and that the latter represented the time of the first appearance of the one-celled animals, the protozoa (See Chart II, Chapter VII). In that case, the former would have been the Age of Volcanoes and the latter the Age of One-celled Animals. This supposition, however, has been changed for the reason that the more man learns about the oldest parts of the earth, the farther is the

THE CHART

ERAS	PERIOD	APPROXIMATE LENGTH IN YEARS	DOMINANT LIFE
Archeozoic		Over 50,000,000 years	Age of volcanoes. Age of one-celled life (Theoretical).
Proterozoic			Age of primitive marine invertebrates. First known fossils.
Paleozoic	Cambrian Ordovician	8,600,000 5,400,000	Age of shelled invertebrates.
	Silurian	5,000,000	Age of fishes.
	Devonian	8,000,000	
	Carboniferous	2,500,000	Age of amphibians.
Mesozoic	Triassic	2,500,000	Age of Reptiles.
	Jurassic	3,600,000	
	Cretaceous	7,000,000	
Cenozoic	Eocene	5,000,000	Age of mammals and modern plants. Age of grasses.
	Oligocene and Miocene		
	Pliocene and Pleistocene	500,000	
Psychozoic		40,000	Age of mind.

Thickness of rock layers from [illegible]. Other information adapted from various

OF THE AGES

PLANT LIFE	ANIMAL LIFE	THICKNESS OF STRATA
One-celled plants. Water life. No fossils.	Primitive one-celled animals without skeleton. No fossils.	No data.
Cryptozoön (calcareous algæ). Few fossils.	Higher forms of protozoa, as radiolaria, and foraminifera.	No data.
Low forms of non-woody plants, as sea-weeds.	Sponges, jellyfish, worms, etc. Molluscs and blastids. Trilobites dominant.	24,000 feet.
Indications of primitive forms of land plants. First appearance of fungi.	Corals, primitive armored fishes.	33,000 feet.
Delicate ferns with little woody structure. Upper: woody plants, primitive ferns, and evergreens, rushes, tall ground pines, horse tail, club mosses.	Molluscs abundant. First crabs and first land shells (snails). Amphibians appeared. Cartilaginous and ganoid fishes abundant. Primitive sharks.	18,000 feet.
Coal forming plants (mostly seedless); soft and spongy woody evergreens, rushes, fern-like trees. Only traces of low order of flowering plants.	First crayfishes, cockroaches, centipedes, spiders, lung fishes, amphibians dominant. Later: Earliest reptiles.	31,000 feet.
Reduction of coal measure plants, large rushes, tree ferns, many genera of cycads and conifers.	Cuttle fishes appear. Bony fishes first appear. Rise of dinosaurs. *First marsupial mammals.*	5,000 feet.
Age of cycads. Continuation of Triassic flora. Rushes, modern tree ferns, and conifers, ginkgos.	Ammonites, rise of primitive birds (especially terrestrial) and flying reptiles, insects, giant reptiles. Cuttle fishes.	6,000 feet.
Comanchian. Rise of flowering plants, grasses and oaks. Cycads disappearing. Magnolia, fig, sassafras, birch, walnut, maple, etc. Introduction of angiosperms.	Ammonites decline. Rise of toothed birds (especially aquatic), bird-like reptiles, snakes. Later: extinction of great reptiles. *Small primitive mammals.*	12,000 feet.
Increase and development of modern plants. Prominence of grasses. Cretaceous palms become common throughout the world.	Modern shell fish. Vanishing of primitive mammals. Land birds appear. Primitive forms of the modern carnivora and herbivora. Whales. *Lemurs.*	10,000 feet.
Modern plants struggling with the elements of nature.	Development of modern molluscs. Rise and culmination of the great mammals. *Anthropoid apes.* Horse and other modern vertebrates. Transformation of man-ape into man. *Pithecanthropus erectus.*	8,000 feet. 4,000 feet. 3,000 feet.
Domesticated and hybridized modern plants.	*Man.* Rise of civilization and of *"mental"* life. Domesticated and hybridized modern animals.	

authorities as: Williams, McCabe, Lane, Thompson, Dana, Chamberlin, etc.

"origin of life" pushed back into the obscure mist of the fiery age. Although no fossil forms have been found in the rocks of the Archeozoic Age, there are many indications of sedimentary deposits. These show the presence and action of water, as well as conclusive proofs that a lowly type of life existed in those far-off fiery times. The presence of such formations as carbonaceous slates, which derived their carbon from organic sources, and limestones and cherts, which were originally formed from organic matter, imply the existence of

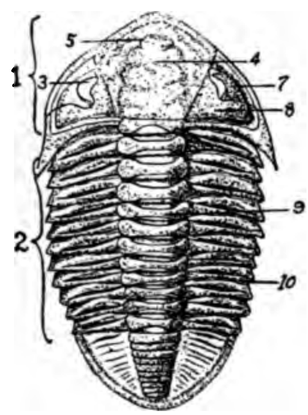


FIG. 15. A type of trilobites which swarmed the ancient seas. 1. Head. 2. Thorax and abdomen. 3. Eye. 4. Glabella. 5. Axial furrow. 7 Free cheek. 8. Fixed cheek. 9. Axis of thorax. 10. Pleura.

life. Consequently, the various writers of recent years seem to be justified in placing the first-considered age in the "zoic" (Life) group and calling it, at least the latter part, the Age of One-celled Animals—the Archeozoic, rather than Archean.

It was thought until quite recently that no fossil remains of plants and animals were to be found even in the rocks of the Proterozoic Era. Walcott, however, has recently brought forth some splendid specimens of radiolaria and foraminifera (Protozoa), and also some low forms of plant life (Algae) as well as traces of worms.

Paleozoic.—It will be noted from the map (Fig. 12) little of North America projected above the vast expanse of the seas in the early part of the Paleozoic (Ancient Life) Era. Even if there had been a high form of animal life in existence at that time, we should not expect to find the remains of that life distributed very extensively over the present continent. Those animals would of necessity have been confined to a relatively small land surface. The seas of the early Paleozoic Era swarmed with a great variety of life. The fact that many forms of Cambrian life were present in relatively complex organisms, shows clearly that life must have existed upon the earth millions of years before the formation of the oldest known fossiliferous rocks. The trilobites (Fig. 15), for example, which represented the dominant life, belong to one of the highest of the groups of invertebrate (non-backboned) animals. Among the many other forms which inhabited the seas of early Paleozoic times, the sponges, corals, worms, and molluscs were especially abundant.

The Ordovician and Silurian Periods of the Paleozoic Era (See Chart of Ages) are sometimes called the Age of Molluscs, because of the wide distribution of giant shelled animals coming under that group. Many of these shelled forms are generalized types of the ancestors of the present-day chambered nautilus, from a description of which Holmes sang the memorable stanza:

"Build thee more stately mansions, O my soul,
As the swift seasons roll!
Leave thy low-vaulted past!
Let each new temple, nobler than the last,
Shut thee from heaven with a dome more vast,
Till thou at length art free,
Leaving thine outgrown shell by life's unresting sea!"

Such early forms were very numerous in this age and were often of very great size. Specimens have been obtained which are ten inches in cross section and fifteen feet or more in their longest dimensions. These animals were the most aggressive tyrants of those primitive seas.

Later Paleozoic.—In addition to the profusion of invertebrate life that swarmed the great seas, certain types of early vertebrates appeared about the middle of the Paleozoic Era, and immediately began to increase with remarkable rapidity. It will be observed in the summary of the animal kingdom referred to above (See Scroll of Animal Life, Chart II, Chapter VII) that the earliest of the vertebrates were fishes and fish-

FIG. 16. Armored fishes of the Lower Devonian of Europe. (From Koken.)

like forms. The same scale is noted in the appearance of vertebrates upon the earth (See Chart of Ages), the earliest of them being certain queer armored fishes (Fig. 16), which were lower than the common fishes in the scale of organization. The characteristic primitive fishes were sharks, lungfishes, and gars. Those early fishes, spoken of as *generalized forms*, possessed the characteristics of both amphibians and true fishes. Thru many transitions they finally gave rise to each of these great groups of animals. So abundant were these lowly forms that the middle Paleozoic Era has rightly been named the *Age of Fishes.*

Throughout the millions of years which elapsed during the middle and late Paleozoic Era remarkable changes took place in the scale of animal life, due to the ever-changing environment. Animal life began to appear on the land in a very primitive form. Among these air breathers, spiders and scor-

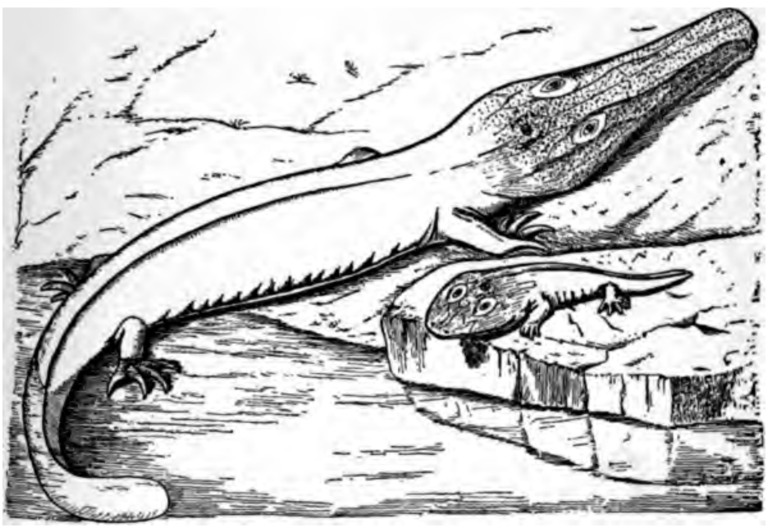


Fig. 17. A large Stegocephalia (above) 5 feet long, and a smaller form, Branchiosaurus, 6 inches long. The significant feature for our present consideration is the presence of a third (pineal) eye. (See text.) (From Schuchert.)

pions preceded a great group of insects such as cockroaches, dragon flies, etc. The most advanced step up the scale of life is noted in the extension and further development of the amphibians, which were the first true land vertebrates. These animals, which averaged six or seven feet in length, and in appearance slightly suggested the common lizard of to-day, were small in comparison with the great giants which followed them. These primitive amphibians (Fig. 17) continued to deviate until they developed into a higher form of amphibian on the one hand and into a generalized or lizard-like reptile on the other.

While animal life was advancing so rapidly, the plants were also undergoing progressive steps in evolution. From the primitive forms represented by seaweeds and certain other non-woody plants of the early Paleozoic Era, came strange groups of woody plants. Luxuriant vegetation, composed of

FIG. 18. A typical Pennsylvanian carboniferous swamp, as restored by Unger. (From Pirsson and Schuchert, "Text-Book of Geology," by courtesy of Professor Schuchert and John Wiley and Sons.) These great tree ferns of antiquity played a part in preparing fuel for civilized man of to-day.

many kinds of early tropical plants, ranging from delicate ferns to gigantic fern-like trees over one hundred feet in height and three feet in diameter, covered practically the entire land surface.

Knowing as we do that coal had its origin in these ancient plants, we experience a peculiar sensation when we are lowered into a coal mine for the first time. We are reminded of the vast forests of the Carboniferous Period and the wonderful transformation that took place when they were buried. In picturing such a forest (Fig. 18), Schuchert says: "It was a forest of rapid growth, of soft and even spongy woods, in which evergreen trees with comparatively small, needle-like leaves were prominent. Associated with these were thickets of rushes, also of very rapid growth, which in habit resemble the living cane brakes and bamboo thickets. Here and there

Fig. 19. Fern leaves as commonly found preserved in rock strata. Such rocks tell us the true story of the plant life of the past.

stood majestic fern-like trees, while many smaller ferns and fern-like plants thrived in the shady places or climbed about the trees. Shades of green were the dominant colors, and the monotone of the verdure was nowhere enlivened by bright flowers. Such, however, were sparingly present, but in a low order, insignificant in size, and unattractive in color. At the time when the trees and ferns were liberating their spores the entire forest was covered with a greenish-yellow or brown dust. The air was not scented with sweet odors, for there was no honey, but it is probable that resinous smells such as pervade living conifer forests were present" (Fig. 19). With an equal amount of interest, Shute appropriately reminds us: "As yet no snakes or turtles, no alligators or crocodiles had come into existence. In spite of the fact that great advance in animal life was made during Carboniferous times, there was little of the life in those ancient woods that we associate with the forests of the present; they were gloomy wastes of shade, without the presence of bright flowers, no humming of the bees, no song of birds, and few sounds save the gurgling of running streams, the sighing of the wind thru the leaves, the splashing of waves upon the shore, and the bursting of the thunder clouds. The interest and importance of the Carboniferous Amphibians as the first land backboned animals is so great as to cause the Carboniferous Period to be spoken of as the *Age of Amphibians*."

Mesozoic Era.—Among all the changes in various plant and animal groups which are recorded in the rocks, those between the Paleozoic Era and the Mesozoic Era (Medieval Life) are the most interesting. Contrast, if you will, the experiences of a naturalist who might fancy he was visiting the strange lands pictured above, with his experiences should he visit those of the next succeeding era, the Mesozoic. Instead of crowding thru the most luxuriant thickets of ferns and horsetails, the naturalist would find, in the Mesozoic, a higher order of plants represented by fairly modern "trees," such as the cycads and conifers. The more or less desert-like climate that prevailed during the early Mesozoic Era served as a check upon the growth and propagation of such dense vegetation as existed in the Carboniferous Period. In the districts that were swampy, however, the brakes of rushes were sufficiently dense as to be similar to our present southern cane brakes. Knowlton reminds us that the climate was warm and subtropical, which fact was shown by the absence of annual growth rings on the trees, indicating the lack of marked seasonal changes. As the age progressed, the cycads became so much more abundant than the other forms of vegetation that the middle Mesozoic Era (Jurassic) is known as the *Age of Cycads* (See Chart of Ages). The latter part of the Mesozoic Era (Cretaceous) marked a noted advance in the history of plants. The ordinary hardwood trees began to appear for the first time. It has been estimated that fully ninety per cent

FIG. 20. Strange animals which inhabited the Cretaceous Seas (see Map, Fig. 13) of Kansas, millions of years before man appeared on earth. 1. A wingless reptilian bird—Hesperornis. 2. A Plesiosauria, 50 feet long. 3. Flying dragon—Pterosaurs. 4. A fish-lizard. 5. Winged reptilian birds. After Williston. (By courtesy of the University of Chicago Press.)

of the plants existing at that time were of kinds (tho of different genera and species) known at the present time, such as the oak, hickory, maple, poplar, beech, etc. It must not be presumed by the reader that these trees were like the ones that are so familiar to us now. They were quite different in certain respects, although they were the forerunners of the present varieties.

The most conspicuous group of animals in the different divisions of the Mesozoic Era, and the one which was indeed the all-dominating master of the earth at that time, was that of the reptiles. Indeed, so masterful were these huge monsters that, from the standpoint of animal life, this entire age has been properly called the *Age of Reptiles*. Not content as

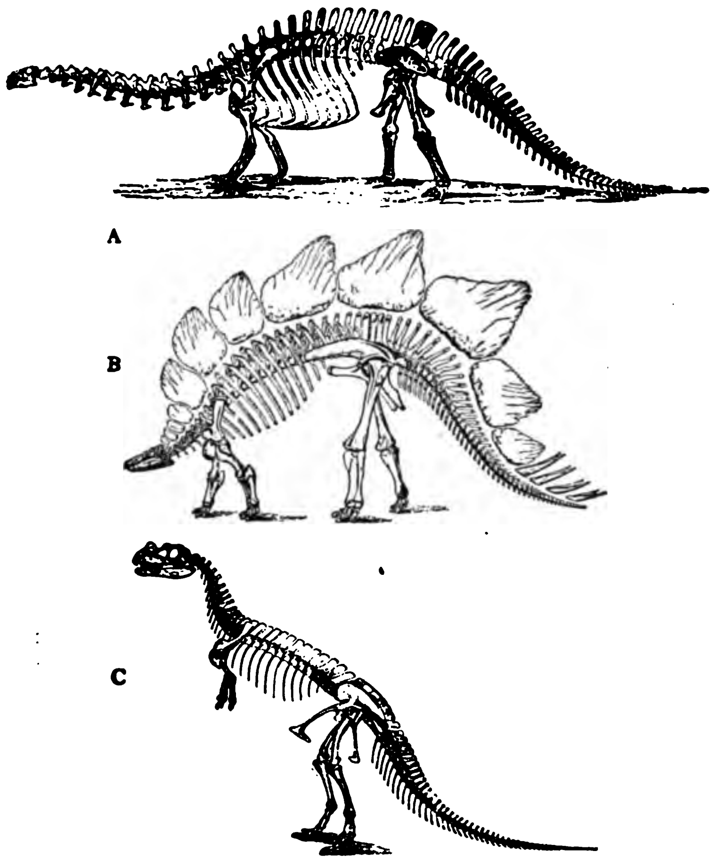


FIG. 21. Three types of fossil reptiles which constituted the dominant life of the Mesozoic. A, *Brontosaurus excelsus;* B, *Stegosaurus ungulatus;* C, *Ceratosaurus nasicornis.* (By permission, from Hegner's "College Zoology," The Macmillan Co.)

rulers of the land, they are known to have swarmed the seas and even the air (Fig. 20). How realistic would their powers seem could man but step back a few ages and explore the tropical lands of those bygone days. From one direction one might see a gigantic monster some eighty feet long (Lull) and weighing many tons, sluggishly moving over the semi-marshy country; near the water's edge might appear a long, snake-like neck, 20 ft. long (2, Fig. 20) belonging to some hidden monster of the sea; overhead might be heard the snapping of

FIG. 22. Bone from one of the animals which once inhabited the marshy coasts of the Kansas Sea. Remains of these monsters are not uncommon in Eastern Colorado, Kansas, and adjoining states. Note the size as shown by the ruler and in comparison with the human femur.

the sharp teeth of one of those great reptile-like birds (3, Fig. 20). Shute speaks of them thus: "Some walked on all fours; others were occasionally or usually bipedal, and walked upright like birds, and had many structural features in common with the latter; some were herbivorous (Fig. 21, A and B), feeding on plants and even reaching into the branches of the trees for their food; others were carnivorous (Fig. 21, C), feeding on their fellow-creatures. Huge reptiles (Ichthyosauria) swam about in the sea in great numbers. Immense bat-like forms (Pterosauria) sailed thru the air like birds, being literally flying dragons" (Fig. 20).

The birds of the Mesozoic Era, especially of the latter part, were so much like the flying reptiles that a separate discussion of them is scarcely necessary. In fact, the two groups were at first the same—the primitive reptile-like birds having separated from their monstrous ancestors a little later in the era. This is a fact of great significance in the process of evolution, and it is well established by the abundance of fossils which clearly show the connecting links between the reptiles and the birds. With the fishes and shelled animals, the ***building of higher life*** still continued. The number of shelled animals of the earlier days were surpassed in this period by the chambered ammonites, and, in like manner, the ganoids and sharks were largely supplanted by the bony fishes.

Perhaps the most momentous fact from the standpoint of the evolution of man was the appearance for the first time of mammals. Although they were of an extremely low order, many having distinct reptilian characteristics, and belonging to the generalized forms, such as the monotremes and marsupials, they were truly the ancestors of our higher animals and of man himself. Perhaps the nearest living relative to these extinct animals is the opossum. Chamberlin and Salisbury, in speaking of the mammalian life of the Mesozoic Era, said: "Of peculiar interest is the appearance of early forms of non-placental mammals. They were small, and so primitive in type that it is not altogether certain that they were mammals; but they are commonly regarded as such, with kinship to the marsupials. Their appearance while reptiles were yet dominant suggests that mammals diverged from the primitive stock much earlier. In view of the mammalian dominance of later times, it is noteworthy that the non-placentals developed but slowly and feebly during the Mesozoic Era. It is an open question whether placental mammals are the descendants of the Mesozoic non-placentals, or whether they had an inde-

Fig. 23. Carnivorous Dinosaur, Ceratosaurus. These kangaroo-like animals, some 20 feet in length, were masters of the strange Comanchian forests. (By permission, from "Nebula to Man," by Henry R. Knipe, published by E. P. Dutton & Co.)

pendent origin. . . . The marvelous development of aquatic and terrestrial reptiles and of birds makes the scanty record of the *mammals* all the more singular. Only a few jaw bones of the size of those of mice and rats have been found. These low types are referred, without complete certainty, to marsupials. They appear to have been insectivorous."

What hopes could be placed in a race of animals no larger than our smaller cats when they lived and moved in a land of giant reptiles? These small creatures probably served as food for their enemies, but a small remnant of them, thru persistent hiding and a later adjustment to a new and changed environment, carried their small amount of warm blood into the great mammals of the succeeding ages and contributed the vital fluid for the building up of a race of beings that assumed an upright position, and later walked this earth, mastered it, and blessed it with civilization.

Cenozoic Era.—The plant life of the Cenozoic Era (Modern Life) was substantially the same as that of the late Mesozoic, since the latter gave birth to the modern types of vegetation. The Cenozoic Era was characterized by the predominance of land plants of various kinds, consisting chiefly of such flowering plants as "flowers," grasses, bushes, and trees (See Chart of Ages). Later, the low forms of flowering plants, such as the cycads and conifers, were less prominent than in the early Cenozoic and late Mesozoic. The non-flowering plants, such as the lichens and ferns, were so much less abundant than during earlier times that they might be said to be on the road to extinction. By far the most characteristic form of vegetation of the early and middle Cenozoic, and the type which rendered the greatest influence upon animal life, was the grasses. The great open plains, which were so common, were matted with grasses which served as great pasturages for the developing of herbivorous animals. Altho, as it will be noted, the grasses made their appearance as early as the Cretaceous Period of the Mesozoic Era, they did not spread very rapidly until well into the Cenozoic Era.

The prominence of grasses during the Cenozoic Era suggests not only a marked change in the environment but also a general change in the evolution of animal life. The insignificant little mammals that found the lowlands of earlier days so unfavorable, especially as they were continually harassed by the smaller "dragons" and trampled under foot by the great reptiles, struggled into the early Cenozoic with an increased hope for survival. This was especially true of the herbivorous mammals which appeared as an offshoot of the primitive generalized ones, since the grassy plains were more

FIG. 24. The Great Mastodons (*Americanus*) roamed the valleys of America before the modern animals, as we know them, made their appearance. (From Chamberlin & Salisbury, "Geology," Henry Holt & Co., after a painting by Gleeson in the National Museum, Washington.)

favorable for them and less favorable for their snake-like enemies which were beginning to lose their supremacy. Although actual combat probably was of little significance as a factor favoring extinction, the disadvantage of changed environmental conditions might be illustrated by imagining one of these great reptiles in pursuit of a Cenozoic mammal. Should the race be in the marshes, the former, tho with four stubby legs, by gliding over the wet ground, would soon overtake the latter, as he would be hampered by the mire; However, should the race be across the grassy prairie, the mammal could not only easily escape the reptile, but he might turn and become the pursuer. The hard ground would be favorable for a running animal and unfavorable for a "mud boat" animal.

As a result of this changed environment, which presented more favorable conditions for the animals of the dry land and grassy plains, the ponderous reptiles gave way to mammoth elephants (Fig. 24), which are more familiar to us than the earlier and more peculiar forms of life. These early elephants differed from our modern variety principally in that they were much larger. On the other hand, the reptilian birds (Fig. 20) of the air surrendered their places to the modern birds; the "dragons of the deep" having disappeared, the modern fishes had more nearly an equal chance with the hard-shelled varieties, which were still active. In late Cenozoic times, the mammoth land animals surrendered their places to the smaller and more adaptable ones, such as the bison, wild cattle, and wild horses. In our own day these last mentioned animals have been largely replaced by domesticated species. In like manner, the birds of the forests of only a few years back seem to have been doomed and their places to have been taken by domestic fowls and "domestic birds," typically chickens, pigeons, robins, and sparrows.

The sea-dwelling animals were also changing rapidly. The first mammals to adapt themselves to an oceanic life did so in the early part of the Cenozoic Era in the form of a primitive, whale-like animal. Then appeared the sea-cows and still later the sea-lions, seals, and the true or modern whales. The changes in the invertebrate life were even more interesting, as a single illustration will suffice to show. Should it be possible for the American butchers to import oysters from the Californian seas of the middle Cenozoic Era (Miocene Period), their customers would not buy fresh oysters by the dozen or the quart but rather by the slice—they would call for it much the same as we do for a pork steak to-day. These giant oysters were often more than a foot in length, eight inches in width, and six inches in thickness. It is interesting to note that one of these giants would be roughly equivalent to nearly three

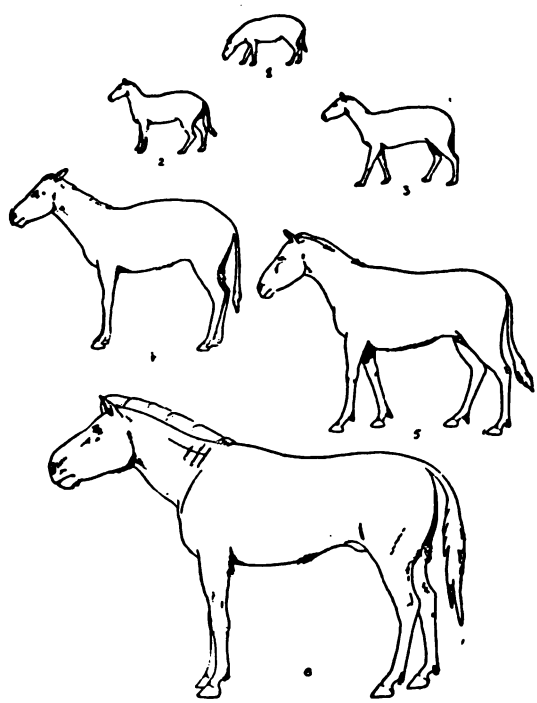


FIG. 25. Six stages in the Evolution of the Horse. 1. *Eohippus*, Lower Eocene, the primitive four-toed ancestor. 2. *Orohippus*, Middle Eocene. 3. *Mesohippus*, Oligocene. 4. *Merychippus*, Miocene. 5. *Pliohippus*, Pliocene. 6. *Equus scotti*, Pleistocene. (From *Yale Alumni Weekly*, by courtesy of Professor R. L. Lull.)

gallons of fresh oysters as we know them, and would retail for about ten dollars.

Another branch of the animal kingdom which began to appear out of the evolutionary mist of the Cenozoic Era has attracted more attention and caused more heated controversy than all others combined, because it marked the road of progress toward modern man. These animals, the lemurs (Fig. 26), had skeletons somewhat similar to those of man. Prior to the Cenozoic Era, there is no indication whatever of any form so advanced in the scale of life. This one fact within

Fig. 26. A modern Lemur whose geologic ancestor probably served as a link in the evolution of man. (From "Mammals," by Flower and Lydekker, by permission of A. & C. Black, Ltd., London, England.)

itself should be sufficient to condemn the "seven day" notion. If God "created" man only a few hours after the lower animals, such as the mussels, fishes, etc., why do we not find his remains in the rocks of those early ages together with those of the other animals? The texture of man's bony framework is fully as resistant as that of the remains which we do find.

This one fact conclusively shows that man's introduction upon this globe was brought about some forty or fifty millions of years after some of his lower ancestors. Further substantiation is furnished by the fact that none of the bones of the common land animals of to-day—the bones of which have been the most likely to remain had they been in existence—are to be found in any of the rocks prior to those of the Cenozoic Era. Is it not surprising that many really intelligent leaders still contend that the "seven days" as used in the Biblical creation story contained only twenty-four hours each? If the orthodox leaders expect the generations of to-morrow to accept the creation story, the "seven days" must be lengthened not only to seven million years but rather to *considerably more than seven times seven million years.*

In the rocks of the early Cenozoic Era, the Eocene Period, remains are found of a primitive mammal which suggests the appearance of a higher race. From this primitive and generalized type more nearly resembling the lemur (Fig. 26) than any other modern form, there were evolved many, if not all, of the present-day forms which have a more or less upright posture, the primates. The following outline, which was compiled from the statements of several authorities, gives the chronological order of the steps in the development of the primates, and, tho condensed, graphically shows *man's place in nature* in so far as has been ascertained.

1. Various invertebrates
2. Balanoglossus, Amphioxus, and other lower Chordates
3. Lamprey and hag-fishes
4. Sharks
5. Lungfishes
6. Primitive amphibians
7. Primitive reptiles
   a. Modern snakes
   b. Reptilian birds with teeth
      1. Modern birds

8. Reptilian mammals (Monotremes)
9. Marsupials
   a. Modern quadruped mammals
10. Insectivores (Moles, hedgehogs, and shrews)
11. Generalized lemur-like animals (Eocene Period)
    a. Modern lemurs (Fig. 26)
12. Generalized monkey-like forms (Oligocene Period)
13. Generalized ape-like forms (Miocene Period)
    a. Modern gorilla
    b. Modern chimpanzee
    c. Modern gibbon
    d. Modern orang-utan
    e. Extinct apes of Miocene Period
14. Many unknown ancestors of man
15. Pithecanthropus erectus (Ape-man of the Pleistocene—(Fig. 27) more than 500,000 years ago)
16. Missing links
17. Eoanthropus (The Dawn-man)
18. Homo heidelbergensis (The Heidelberg Man—250,000(?) years ago)
19. Big-headed savages (Neanderthal Men of the Old Stone Age. 60,000 to 150,000 years ago) (B. Fig. 28)
20. Men of the Later Stone Age (Aurignacian Men), Originators of the fine arts (Fig. 29). (50,000 (?) years ago)
21. Men of the Late Stone Age (Magdalenian Men)
22. Men of the Copper Age (5,000 or 10,000 years ago)
23. Men of the Bronze Age (4,000 years ago)
24. Men of the Iron Age (In Palestine 3,000 years ago)
25. Men of the Coal Age (In England 500 years ago)
26. Men of the Electrical Age (America. Latter part of Nineteenth Century)
27. Men of the Flying Age (Middle of Twentieth Century)

It is to be noted that the primitive lemur-like animals (11 in the outline) can boast of a long line of ancestors thru the ages, tho their heritage is at many places somewhat uncertain. Although these animals are used as the more definite starting point in the history of man, *it must not be concluded that man came from lemurs* or even that man and lemurs developed along the same line with man in the advance. The more logical view is that they both branched from one common ancestral stalk. The primitive and generalized lemur-like animals, which gave rise to two distinct lines of heritage, the lemurs and a higher form of monkey-like animals, were perhaps derived from the insectivores (moles, shrews, etc.) since they show many affinities with this group. The geologic appearance of the insectivores suggests that they were derived from primitive marsupials (Opossum-like animals), which came from the primitive reptiles thru a peculiar reptilian mammal-like form (Monotreme). The primitive reptiles serve as another splendid example of how evolution follows two distinct lines. In addition to giving rise to the reptilian mammals and the higher forms under consideration, they are the ancestors of the extinct "flying dragons" (Fig. 20) which are responsible for the appearance of the modern birds. The birds, therefore, are entirely out of the line of human evolution. These primitive reptiles gave rise to a third branch which culminated in the modern snakes. Perhaps the best living exemplification of those primitive reptiles is the three-eyed lizards (Sphenodon) of New Zealand. It will be noted that the amphibians (Mailed frogs), fishes, and invertebrates are further back in the line of heritage.

The above outline shows that the primitive monkey-like animals of the middle Cenozoic Era (Oligocene), which originated from the ancestors of the lemurs, in time gave rise to a primitive animal which was the ancestor of the Miocene apes. These ape-like animals gave rise to two distinct types of animal life: in one direction to the ancestors of man (14 in the

Fig. 27. *Pithecanthropus erectus* (the monkey man walking erect). Extinct primate apparently intermediate between man and the anthropoid apes, the remains of which were discovered by the Dutch Naturalist, Dubois, in the Pleistocene beds of Java in 1891. (By permission, from "Nebula to Man," by Henry R. Knipe, published by E. P. Dutton & Co.)

outline); in another direction to such animals as the gorilla, the chimpanzee, the gibbon, the orang, and extinct animals of the Miocene Period. *To this extent monkeys are the ancestors of men.* The primitive form from which these two branches grew were neither monkeys, apes, nor men, but a generalized type which gave rise to the present forms. In other words, the present forms are "chips off the same block." Why should there be any controversy over this matter when both "chips" differed from the old "block" which lived in the dark mist of the ages millions of years ago? McCabe suggests that: "We may at least assume that the ancestors of man were on a level with the anthropoid ape in the Miocene Period."

Altho we have no certain and indisputable records of man's early history on earth, the ape-man (Pithecanthropus erectus, Fig. 27) found in the Pleistocene beds of Java (1891) established the fact that his development was well under way in the late Cenozoic Era. The presence of certain disputed implements, "Eoliths," suggests that the *evolution of intelligence* had begun long before that time.

Among the many other "missing links" which have been supplied within recent years, the one representing the oldest known human family in Europe, thus called the "Dawn-man," is worthy of mention. These remains, which were found in 1913 in Sussex, England, show that this early race possessed a "snouty," animal-like face; tho they had a brain capacity only a few ounces below that of civilized man. Pirsson and Schuchert say of him: "The prognathous (snouty) face and powerful jaws, with their large teeth, especially the canines, show that Eoanthropus (Dawn-man) was a human brute, hunting and defending himself in the main with his fearful biting mouth. He was still a primitive slayer, tho keener than any of his animal associates, and was destined thru the manufacture of better implements to become a hunter of a higher order." A form most nearly related to the "Dawn-man" is the "Heidelberg-man" found at Mauer, near Heidelberg, Germany, in 1907.

If certain other "missing links" are disregarded, the next in order of the ancestors of man were the men of the Old Stone Age. These men are spoken of as Neanderthal men, being so named from the valley in which their remains were found. They were big-headed savages. Since some fifteen or twenty skeletons of men, women, and children have been found in Belgium, France, Gibraltar, and Germany, quite definite facts are known about these strange people. As the picture (A, Fig.

Fig. 28. Three stages in human evolution. Restorations to suggest the probable appearance of primitive types of human beings. From left to right, *Pithecanthropus erectus* (Java), *Homo neandertalensis* (Germany), and the "Man of Cro-Magnon," *Homo sapiens* (France). These photographs are from the figures moulded by Professor J. H. McGregor on the basis of fragments of primitive man discovered from time to time in various parts of the world. (From Gruenberg's "Elementary Biology," by courtesy of Ginn & Co.)

28) shows, the men of the Old Stone Age had faces which were quite different from those of any civilized race. "The nose was of unusual size and width, the upper lip was very wide, and at the base of the forehead there was a very prominent and continuous brow-ridge that extended from temple to temple." One of the most pertinent facts as viewed from the standpoint of evolution is that these savages possessed a feeling of religious instinct. This is clearly shown by the paintings, food, and stone implements which were found in their burial places.

These indicate that they had primitive burial customs. Although the Neanderthal race was much more highly developed than any of its predecessors, it could not cope with the

Fig. 29. Outlines of Primitive paintings, by Aurignacian Men, of animals from cavern walls of Font-de-Guame, Dordogne. The horse, ibex, cave-bear, wild cattle and reindeer are represented. (From Osborn, after Breuil.)

mighty race, Homo sapiens (wise men, C, Fig. 28), that now began to appear.

Since it is not the aim to give a lengthy consideration of the later races of men, it will suffice to say that quite definite facts are known regarding man's history from his first appearance as a savage, down to the present time. A mere reference will be made to these later races. The Aurignacian men represented a much higher type than the last-mentioned people in that they could make and use better implements. They made shell and ivory ornaments, such as beads and bracelets. It was these people who seem to have been the true originators of the fine arts, representative specimens of their paintings (Fig. 29) and sculpture having been found in many caves in France. The fact that they wore clothing and followed regular pursuits is shown in their colored paintings, in which "garmented women are seen herding cattle and men chasing wild animals." "Count Begowen and his three sons discovered in France, June 1918, on the walls of the subterranean galleries, some engravings estimated to be 30,000 years old, and in such quantity and variety that the extraordinary ensemble of prehistoric art work constitutes a veritable museum. The animals figured in the cave are many, and include reindeer, bison, horses, isolated and in groups; bears, elephants, and rhinoceroses. The representations of felines are rare in prehistoric art. M. M. Begowen has photographed in their cave a genuine lion, executed in bas-relief. They have made out several birds, including swans, ducks, as well as three predatory night fliers. Human figures are likewise represented in the cave. . . . a silhouette particularly remarkable, almost baffling. It represents a man in motion—a man of wonderful body, whose head and shoulders are joined by an enormous neck; whose upper and lower limbs and hands and feet are perfectly human, but whose vertebral column is prolonged in an exterior appendage resembling that of the anthropoids; a man at least, *qui marche à quatre paties!*" (*Science*, Dec. 20, 1918). The later history of civilized man as outlined is too familiar to need discussion. The Copper, Bronze, Iron, and Coal Ages followed in consecutive order, marking the time when each was adapted to the needs of the growing civilization.

Since the adoption of electricity as a servant of general utility, and the approaching general application of flying machines to modern transportation mark probably as great epochs as did the introduction of coal, should not the "Electrical Age" and the "Flying Age" be added to the already long category of ages which mark the path from "Amœba to Man"?

CHAPTER V

EVIDENCES OF EVOLUTION

Time for Evolution—Paleontology—Comparative Anatomy—Haeckel's Law (Embryology)—Life History of Frog—Life History of Chick—Rudimentary Organs—Relationship Proved by Blood Mixing Tests.

"Evolution is not a force but a process; not a cause but a law."
—Morley.

"The best evidence of any process is to witness its going on."
—Shull.

To those who are versed in the facts of evolution, the story of life as revealed in the rock strata is sufficient proof that all animals, including man, have been evolved from some lower form to the present state of advancement. Authoritative men of science no longer dispute this question. Rudolph Virchow was perhaps the last to dispute that man bore a distinct relationship to Anthropoid apes.

Time for Evolution.—With the average elementary students, who perhaps are good representatives of the people at large, the greatest difficulty in accepting the evolution theory is in the fact that they still hold firmly to the belief that "*The earth has not been in existence long enough for all changes to take place.*" The old idea of "*beginning only a few thousand years ago*" has had its influence. There is no question but that the present factors of evolution, such as environment, struggle for existence, natural selection, elimination of the unfit, amphimixis, hereditary induction, and mutation have been in operation from the first origin of life. Granting this fact, most people are somewhat loath to agree that there has been sufficient time to make an "Edison out of an amœba" as one student very aptly expressed it.

Although it must be agreed that the most accurate of workers cannot fix exact dates to certain geologic events, the facts, as shown by various methods of estimating time, point to an earth much older than had ever been conceived. The best workers still agree with Chamberlin [1] that, while considering geologic time, the use of such expressions as "certain truth," "one year after freezing," and "half hour after freezing" are out of place. It nevertheless remains true that sufficient knowledge has been accumulated to establish the fact that the earth is far advanced in adult life. According to the estimates compiled by McCabe, over fifty million years have elapsed since the beginning of the Paleozoic Era, when plant and animal life was very abundant and had reached a fair state of advancement. As more and more light is thrown upon the life of the pre-Cambrian seas, greater and greater become the estimates of the time since life first appeared upon the earth. Who knows but that the time from the origin of life down to the Cambrian Period was as long as, or longer than, from the Cambrian to the present? In that case man would have had about one hundred million years in which to reach his present state of advancement. Joly estimates 100,000,000 years as being the time that has elapsed since the first formation of water upon the hot crust of the earth. Baltwood estimates the age of certain rocks of Ceylon at from 246,000,000 years to 1,320,000,000 years. Sir G. Darwin suggests 1,000-000,000 years as the age of the moon; and it is certain that the earth is older than the moon! In speaking of the length of time from the first shining of the sun until the time when it will become a cold and dark body (See Chapter III), Thompson says: "It seems, on the whole, most probable that the sun has not illuminated the earth for 100,000,000 years and almost certain that he has not done so for 500,000,000 years.

[1] *Science*, June 30, 1899, Chamberlin's reply to Lord Kelvin—"The Age of the Earth as an Abode fitted for Life."

As for the future, we may say with equal certainty that the inhabitants of the earth cannot continue to enjoy the light and heat essential to their life for many million years longer, unless new sources, now unknown to us, are prepared in the great storehouse of Creation." Regardless of the various estimates of the duration of geologic time, it is certain that sufficient time, whether fifty or a hundred million years, has elapsed for the *Laws of Life* to bring about the evolutionary changes of development from "Amœba to Man."

Paleontology

"Whence we see spiders, flies, or ants entombed and preserved forever in amber, a more than royal tomb."—Bacon.

The story of the geologic succession of animals of the lowest types in the Archeozoic Era to the present ones in the upper crust of the earth, should suffice to convince the average thinking person that animal life has spent these millions of years in a gradual upward trend. If the old superstitions and absurd views, namely, that fossils are "freaks of nature" or "nature trying to mimic God's creation," are discarded, could anyone, even the most skeptical, offer any other explanation for the story of fossils than that they are the remains of animals which lived at the specific age in which the corresponding rocks were formed! This fact being accepted, it is then impossible to refute the theory of relationship of all animal life, as the two doctrines are mutually inclusive. After being forced to the above logical conclusion regarding the kinship of all animal life, the average person is apt to contend that man is not an animal, and thus that the facts of evolution apply only to the lower forms—man having been created in his present form, "in His own image." Coincident with this conclusion, these same people may contend that the men of the Iron Age, the Bronze Age, and the Copper Age are distinctly related to man in the present "Flying Age." Furthermore, they do not dispute that the men of the Old Stone Age bear this same relationship. Where shall we stop as we pass back thru the ages? We are now back to the big-headed savages and still find no trace of man's creation. Since the records are somewhat obscure prior to the existence of these brute-like men, perhaps the skeptical would have him play the rôle of the first *created* man. Indeed a pretty compliment to the Maker to say that the big-headed, brute-like savage is "in His own image"! In fact, when the *common conception of "creation"* is carried to its logical conclusion, the *accepted* doctrine of a divine Ruler of the universe is somewhat weakened. It therefore behooves the churchmen to base their *interpretations* of the Bible upon the established and dependable facts of evolution, thus bringing their Biblical teachings within the range of possibility. To admit evolution does not mean the denial of a Supreme Creator and Ruler of the Universe. Quite the reverse! Evolution connotes a *system* and condemns the idea of "a blind unliving force." No less eminent man than Lord Kelvin said, "It is impossible to conceive either the beginning or the continuance of life without an overruling creative power. . . . Overpoweringly strong proofs of intelligent and benevolent design lie around us showing us, thru Nature, the influence of a free will, and teaching us that all living things depend on one everlasting Creator and Ruler."

In view of the importance of the subject and for the purpose of further showing that man has indeed a part in the many phases of evolution, it seems worth while to consider a few additional evidences in support of these contentions. These further proofs are offered from the standpoint of comparative anatomy, embryology, and certain blood tests. The author is mindful, in giving a brief reference to these subjects, that there is again grave danger of the less observant concluding that man was derived from the lower animals as they know them, rather than being very distantly related to them.

Comparative Anatomy.—If man came into being instantly thru divine creation and is in no wise related to the lower animals, it would be reasonable to expect to find no part of his physical make-up to be in common with that of these animals, except in very rare cases of coincidence. Although a first glance does seem to show much dissimilarity, a detailed

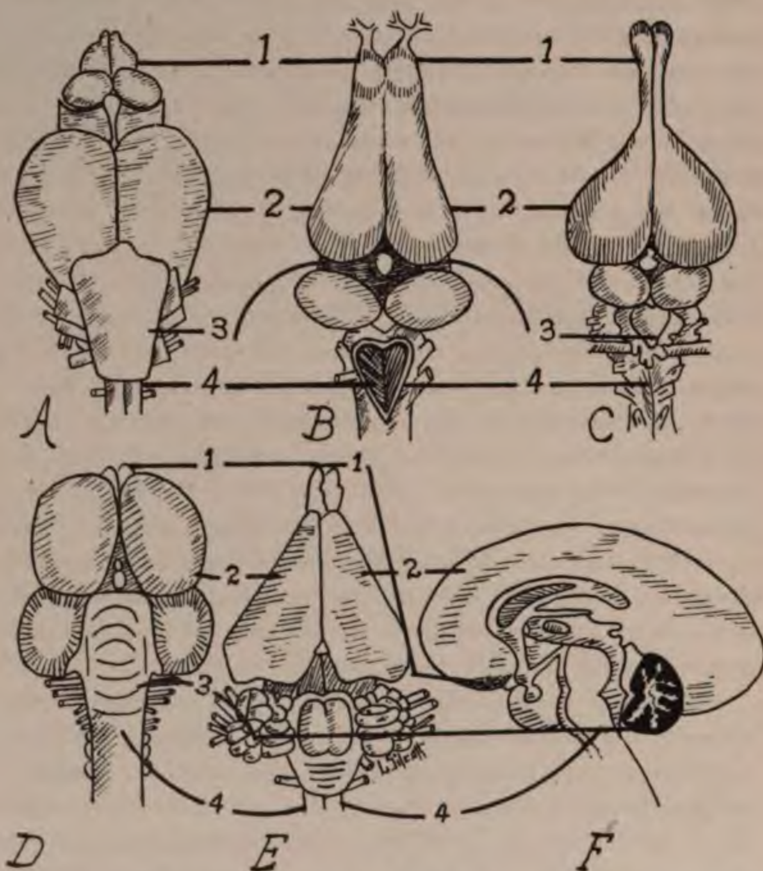


FIG. 30. Comparative study of the brains of various vertebrates. (Redrawn from various authorities.) A. Brain of Salmon. B. Frog. C. Alligator. D. Pigeon. E. Rabbit. F. Human. 1. Olfactory lobes. 2. Cerebral hemispheres. 3. Cerebellum. 4. Medulla Oblongata.

comparison of homologous parts reveals the fact that the structure of man's body corresponds in too many respects with that of the animals' bodies to be explained on the basis of coincidence. Note, for example, the homology of the various parts of the brains of several animals, including man (Fig. 30). As the illustration shows, the complexity of the brain is in direct relation to the stage of advancement of the animal—those with greater reasoning power having the larger brain, especially the cerebrum, in comparison with body size. Compare the small brain and the enormous body of the reptile-like dinosaurs (Fig. 21) with the four-pound brain and the one hundred and fifty-pound body of modern man. Their comparative intelligence shows as great a contrast. This would indicate a corresponding ratio of intelligence between the two, and also that a correspondingly large gap exists between these giant reptiles and man. As evolution progressed, the difference between brain and body weight decreased. Perhaps there is no living animal of to-day that has so small a brain compared with body weight as had the dinosaurs.

In like manner the limbs of various animals are quite comparable with those of man (Fig. 31). The same general advance in the animal scale is shown by this comparison. It is of moment to note that the differences in size and shape of the bones are accompanied by a corresponding difference in the life habits of the individual, or vice versa, as the case may be; however, the homologous bones remain more or less similar regardless of the adaptation to changed environment and habits. Although some use their limbs for burrowing, others for flying, still others for swimming, running, or grasping, they all possess a single bone in the upper "arm," the humerus; two in the lower arm, the radius and ulna; a mass of small bones forming the wrist, the carpals; the long bones of the hand, the metacarpals; and lastly the bones of the "fingers," the phalanges. Such domestic animals as the horse and the cow may seem to be marked exceptions to this rule but an examination will reveal the fact that four "fingers" of the former and three of the latter have degenerated more or less completely.

The above comparisons might be carried on to the other organs of the body and remain equally as striking. The muscular, digestive, excretory, circulatory and nervous systems, as

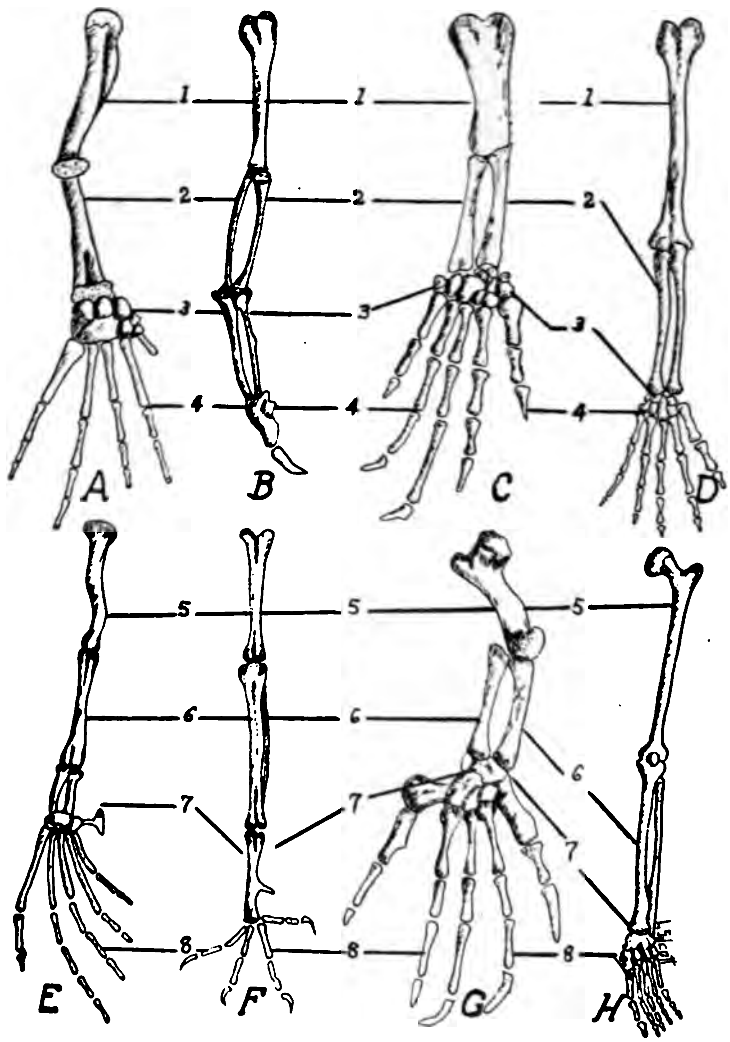


FIG. 31. Comparative study of the arm and leg bones of various vertebrates. If man is not related to the animals, why do the various parts of his body correspond so closely to those of the animals? A. Fore leg of frog. B. Wing of bird. C. Fore leg of tortoise. D. Human arm. E. Hind leg of frog. F. Leg and foot of bird. G. Hind leg of tortoise. H. Human leg. 1. Humerus. 2. Radius and ulna. 3. Carpals and metacarpals. 4. Phalanges. 5. Femur. 6. Tibia and fibula. 7. Tarsals and metatarsals. 8. Phalanges.

well as the organs of the special senses of man, exhibit many elements in common with those of the lower animals. Since the author has heard so much contention from the masses, as well as from college trained people not versed in biology, to the effect that evolution applies to animals only and not to man, he cannot refrain from calling attention to the absurdity of this belief, knowing, as he does, the revelations of comparative anatomy. What must be the state of mind of any individual who would contend that the brains and the limbs (Figs. 30 and 31) of the animals represent evolutionary relationship, but that those of man typify a separate creation, having no relation to the former group? The absurdity of such an assumption is apparent from the illustrations.

Embryology, or the Development of the Individual as Compared with the Development of the Race.—According to Haeckel's fundamental law of biogenesis, "*ontogeny is a brief recapitulation of phylogeny*"; that is, the life of the individual is a brief living over of the life of the race. It might be admitted that this "law," after being almost unanimously accepted for many years, is now questioned if carried to extremes. None the less, it remains true that the facts connected with the development of an individual—whether it be a chick, a pig, or a man—before birth (Fig. 33), lend support to the doctrine of evolution. Conklin ('20) says, "Just as the earth rotates on its axis, revolves in its orbit, and the whole solar system moves thru space, so organisms undergo embryonic development, specific development and phyletic development, all being parts of one great process."

One of the simplest illustrations of the changes that take place in the life of an individual and one which typifies corresponding changes in the evolution of the race, is found in the development of the frog (Fig. 32). Almost everyone is more or less familiar with the life story of the frog. It is generally known that the eggs of this amphibian are deposited in the water in early spring and that they undergo segmentation, or cell division; that is, each egg which is a single cell divides into two cells. These, in turn, divide into four cells, then into eight, then into sixteen, etc. In each case the cells still adhere after they have undergone complete division, thus suggesting the development of the Colonial Protozoa (Fig. 42).

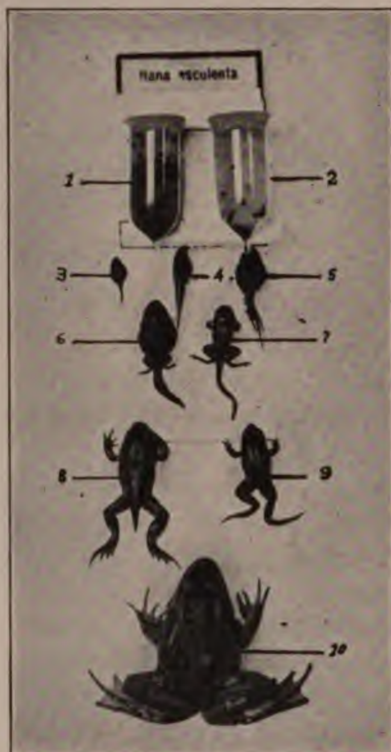


FIG. 32. Metamorphosis of the Frog. 1. Eggs. 2. Tadpoles just hatched. 3 and 4. Older tadpoles. 5. First indication of hind legs. 6. Older stage. 7. Both pairs of legs free. 8 and 9. Successive stages in the absorption of the tail. 10. Adult frog.

The division continues until a mulberry-like ball with a central cavity is formed (Morula stage) giving a crude representation of certain early cœlenterates. The spherical form now elongates into a worm-like tadpole, which by means of suckers attaches itself to the weeds or leaves in the water. A mouth soon appears, and the tadpole begins to feed upon the one-celled animals and plants in the water. This method of feeding suggests a correspondence with that of certain animals in the various geologic ages. For a few days the tadpole breathes with external gills, but later these are replaced by a pair of inside gills which are covered by a fold of skin corresponding to the gill covers (operculum) of the fish (Fig. 51). This is a very typical "fish stage." Locomotion is accomplished by whip-like movements of the tail; the food is the same as that of small fishes; oxygen is taken from the water which enters the mouth, passes over the gills and thence out thru a hole on the left side of the body.

The hind legs appear first in the form of small buds; in like manner, the foreleg buds grow out from the body. As the leg buds appear, the gills are gradually replaced by lungs, and the large tail is absorbed. The animal is now a "frog" and can no longer breathe water like a fish but must appear at the top of the water for air, suggesting the first appearance of air-breathing animals. Simultaneously with these changes, the horny jaws used in scraping algæ from the plants under water are replaced by a set of tiny teeth and a typical tongue. Since it is no longer possible for the frog to feed upon the water forms, it becomes interested in the insects along the bank which it can capture with its slimy tongue. Thus, the frog becomes a typical amphibian, using the water only as a hiding place and for the purpose of moistening its skin. This simple illustration should bear out the fact that "ontogeny" (life of the individual) is, at least, a suggestion of "phylogeny" (life of the race).

Although certain stages in the life history of the frog are suggestive of certain stages in the evolution of other lower forms, it becomes necessary to examine the embryo of higher forms in order to make the story more complete. If the small circular disc on the yolk of an egg which has been in the incubator a few hours be examined with the microscope, a distinct streak (the future chick) will be seen. A little later, this granular streak divides into sections that are suggestive of the segmentations in the higher worms. By the close of the second day, the beating of the tiny heart starts a primitive type of circulation connecting the embryo with the "blood ponds" of the yolk. Since space does not permit a detailed comparison of the changes in the circulation of the chick with those of the adults of certain other lower forms, it will suffice to say that the recapitulation theory is of especial application in this case. An elongated fish-like animal with a very prominent tail now

FIG. 33. Embryos of Various Vertebrates showing a striking similarity during the early stages. "Ontogeny recapitulates Phylogeny." (From Romanes, after Haeckel.)

lives in the egg for a number of hours when the foreleg buds and the hind leg buds of the chick make their appearance. The tail is absorbed as was the tail in the case of the tadpole. Before this process is completed, the gill slits of the chick become quite conspicuous. Figure 33 shows the characteristic "fish" stage of various animals, the gills and tails being very clearly pictured. The appearance of the four leg buds may be noted in the figure. Is it not remarkable that the "foreleg" buds of embryos which are practically indistinguishable will develop into the *hoofed forelegs* of the calf and pig, *forefeet* of the rabbit, *legs* of the tortoise, *tiny feet and legs* of the salamander, *fins* of the fish, *wings* of the chick, and *arms* of the human child?

Furthermore each organ of the human body also tells us something of the past. The liver, for example, which arises as an outgrowth from the intestine suggests the adult liver-like organ attached to the intestine of the amphioxus. As further development continues, suggestive duplications of the adult livers of forms between the lower fishes and man are observed. Thus, as part after part, and organ after organ, make their appearance, each tells the story of its evolution from a simpler and more primitive predecessor. Is it not logical to conclude that these peculiar facts indicate a certain relationship between all animal life? Does not the appearance of a tail, gill slits, primitive liver and kidneys, and blood circulation in the human embryo suggest that man as a race has passed thru the typical stages of animal life below him?

Rudimentary Organs.—A further evidence for the above conclusion is shown very graphically by the presence of rudimentary or vestigial organs in man's body,—the vermiform appendix, perhaps, being the best known of these organs. In addition to the appendix, there are many other vestigial structures in our bodies that point back to our *pre-human* ancestry. The human tail, for example, never entirely disappears but remains in adult life as a posterior projection of the spinal column. Many instances have been reported in which the tail remained quite conspicuous throughout adult life.

The ear should also be classed as a pre-human relic. In the lower animals, the muscles of the ear are still active and can move the shell (pinna) in order to reflect the sound waves into the interior. With man, however, these muscles are so degenerate that the ear cannot be moved and thus it has practically lost its function. In cases where the outer ear has been removed, it has been found that the sense of hearing was scarcely, if at all, affected. Could it not also be concluded that the hairs on the human body are a useless legacy handed down to us by our geologic ancestors?

Among the many other interesting vestigial organs, the pineal body should have special mention. This is a rudimentary organ somewhat larger than a pea located in the center of the brain. As we trace this body thru the various animals down the scale, we find it becoming more and more conspicuous, until in many reptiles, notably the New Zealand three-eyed lizard (Fig. 17), it approaches a normal eye. Examination of the extinct forms of animals indicates that this third eye, which every human possesses in a rudimentary fashion, surely functioned as an organ of sight. Is it not possible that the mythological stories of the three-eyed monsters and of the giants with an eye in their foreheads had their origin based upon a *real middle eye?* McCabe aptly concludes that: "The vestigial structures must be interpreted as we interpret the buttons on the back of a man's coat. They are useless reminiscences of an age in which they were useful."

Proof of Relationship by Blood Mixing Experiments.—McCabe presents another evidence for the organic relationship of animals as shown by certain blood tests that have received considerable attention in recent years. He says: "The blood consists of cells, or minute disc-shaped corpuscles, floating in a watery fluid, or serum. It was found a few years ago, in the course of certain experiments in mixing the blood of animals, that the serum of one animal's blood sometimes destroyed the cells of the other animal's blood, and at other times did not. When the experiments were multiplied, it was found that the amount of destructive action exercised by one specimen of blood upon another depended on the nearness or remoteness of relationship between the animals. If the two are closely related, there is no disturbance when their blood is mixed; when they are not closely related, the serum of one destroys the cells of the other, and the intensity of the action is in proportion to their remoteness from each other. Another and more elaborate form of the experiment was devised, and the law was confirmed. On both tests it was found by experiment that the blood of man and of the anthropoid ape behaved in such a way as to prove that they were closely related. The blood of the monkey showed a less close relationship—a little more remote in the New World than in the Old World monkeys; and the blood of the lemur showed a faint and distant relationship."

Regardless of the convincing evidences presented, it must be admitted that as Shull says "The best evidence of any process is to witness its going on." It will be shown in later chapters that the process of evolution can be and is being observed by numerous workers, and thus that the theoretical has clearly given way to the observational.

CHAPTER VI

THE CYCLE OF LIFE

The "Ups and Downs" of Phylogenetic Life—Man, the All-dominating Power To-day—Who is the Imaginary Super-Man of To-morrow?—Shall Science or Religion Answer this Supreme Question?

"We of today stand midway in the stream of human progress . . . we know that our feet are set on a path of progress, and that it is for us to decide where that path shall lead. Driven from our paradise of primitive simplicity, we have the choice of good and evil, but no longer the option of deciding whether to choose."
—*Cockerell.*

A study of the innumerable fossils which are found entombed in the rock strata of the earth reveals many facts regarding the history of life and the theory of evolution. Such a study, furthermore, presents a graphic story of the "ups and downs" of the various types of plants and animals that have inhabited the earth during the past ages. Altho many animals which had their origin far back in geologic time still exist in modified form, the day of their supremacy has long since passed, and they have become subservient to other and more powerful contemporaries. Those which could not withstand the vicissitudes of nature or could not combat or escape their new enemies vanished entirely, leaving their fossil remains to tell the story of their struggle for existence. Some of the shelled invertebrates, such as the clam, oyster, and mussel, appeared in a primitive form as far back as the early Paleozoic Era and have served as food for various higher animals during all of the ages, at last finding their greatest enemy in man. In like manner, when certain higher forms, such as fishes, made

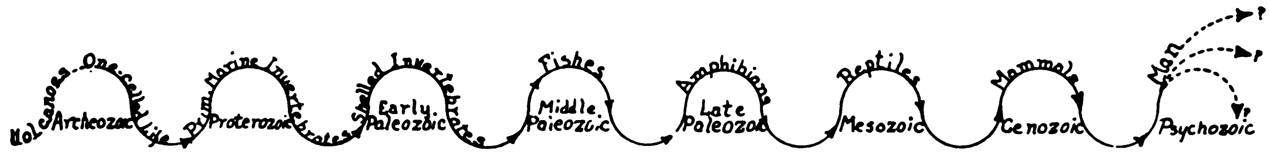


Fig. 34. The Succession of Animal Life.

The accompanying diagram shows the type of animal life which dominated the Earth during various geologic ages. Beginning with the Age of Volcanoes (early archeozoic), animal life developed step by step until civilized man became the dominating master. Although there were many minor fluctuations in the "ups and downs" of life's development, only eight outstanding types of animal forms characterized the evolutionary path from "Amœba to Man." It is interesting to note that of these eight dominating forms the first four lived in the water and the last four lived on land, the link between the fishes and the amphibians representing the transition forms.

The condition of man's evolution during the present or Psychozoic Age is quite problematical. Has man reached the limit of his possibilities, or has he just begun to ascend the scale of human perfection? If evolution continue in the future as it has in the past, what type of being may be expected when the present inhabitants of this earth have passed into oblivion? Such questions are permissible in the realms of both science and religion.

their appearance, they, in turn, served as food for still higher forms that appeared later. Thus, it might be said, the food element has been one of the greatest factors in the struggle for existence, and in the ultimate survival of the fittest. From the standpoint of ages, this factor, together with changed climatic conditions, has caused entire races of animals which once swarmed the earth to disappear entirely or to become subdued by new ones more adaptable to their surroundings.

The accompanying diagram (Fig. 34) illustrates the rise and fall of the great animal groups during the passing of the ages. The *Laws of Life* teach us that no one animal race can reign supreme forever, no more than can certain rulers or nations. Each dominating species increases in numbers and power until it reaches its zenith, then slowly but surely vanishes into insignificance or disappears entirely. The illustration shows that such a rise and fall of world dominance has taken place at least eight times since life appeared upon the earth, each time the masters being a higher form of life than their predecessors. Thus, each new generation of life has been the real master of the preceding race.

At present man is the all-dominating power, having become master of the earth thru his intellectual ingenuity and superiority. What is man's place in this scale of animal progression? Has the whole process culminated in him? If the future is to be judged by the past, in which dominating species held supreme rule for a few million years only to be supplanted by a more powerful race, man will eventually surrender his place on earth to some other more masterful being. What type of being this *super-man* will be, we cannot even surmise. If we assume that the *Laws of Life* continue and that man will reach the height of his supremacy and then pass into oblivion as have all other geologic masters, it is interesting to conjecture whether or not he has reached the height of his power. Since the dotted line in the figure indicates the road that the race of man is to travel, the completion of the chart is a very uncertain task. Should the dots begin before the summit is reached showing that man is still developing upward, or should they begin at the top, or at some descending point? On the other extreme, could we not logically conclude that since man's power lies in his intellect, he is sure of mastery until the end of time? Such are the questions that confront us in this the *Age of Mind*, the Psychozoic.

"Is man isolated in his splendid powers? Is his a voice crying in the wilderness, with no possibility of an answer? It is the function of religion, rather than of science, to answer this insistent question."

—*Cockerell.*

CHAPTER VII

ANIMAL RELATIONSHIPS—THE UNITY OF LIFE

Introduction—The Cell and the Organ—Division of Labor—Kinds of Cells—Cells of Multicellular Animals—Cells that can Perform all Functions—Primitive Forms—Phylum Protozoa—Amœba—Euglena—Paramecium.

"Man is a part of a great whole, the Animal Kingdom, one form among the many thousand forms in which animal organization has found expression. . . . If we would, therefore, fully understand the structure of man, we must, as it were, look at it upon the background which is formed by the other animals, and for this purpose we must investigate their conditions."

—*Hertwig.*

Introduction

While considering the meaning of evolution as outlined in Chapter II, we found that it is possible to trace, step by step, the evolution of the many mechanical devices employed by man. Using this as a basis, an understanding of geologic and biologic evolution was more easily brought about. In the preceding chapters, the general principles underlying the formation and the evolution of the earth and the various theories relative to the origin of life formed a foundation for a brief study of the early types of plant and animal life which inhabited the globe. The present and two subsequent chapters deal with the inter-relationships which exist between the several groups of the Animal Kingdom as we know it to-day. Such a consideration will give a better insight into the various transitional changes of the past, as well as an understanding of the basic principles which are directing the course of evolution at the present time.

When the early biologists wished to classify an animal, an external examination was made, and the specimen was grouped with those of the nearest *external* resemblance. Later, it became necessary to dissect and to study the internal structure in order to compare the anatomical parts as well as the general resemblance. The minute structure of the brain and the circulation of the blood were found to be as vital to a successful classification as the shape of the head and of the body. After the laws of evolution were better understood, even a knowledge of the comparative anatomy of living forms was found to be inadequate for a true classification. It was found that many living animals possessed characteristics of certain forms which have long since become extinct. It, therefore, became necessary to include all known forms, both living and extinct, in the realms of comparative anatomy. This gave quite an impetus to the study of fossils as they bridged the great chasm between many living groups. It was also necessary to know the facts regarding the early development of every animal to be classified. This study was gradually extended backward thru the embryonic life to the first formation of the individual at the time of the union of the sperm and the egg in fertilization. The study of the animal before birth (embryology) was necessitated from the fact that many forms in the embryonic condition resemble the adults of animals lower in the scale of life. It is obvious that a knowledge of the details of development will give a certain clew to the relationships with other forms. Our knowledge, as expressed in our present system of classification, is based upon a study of thousands of generations of both living and extinct forms. The extinct forms lived out their brief lives and then found a resting place in the rocks where they have remained millions of years awaiting the coming of inquisitive man. It should be evident, then, that the whole scheme of classification as used to-day is, in reality, *an expression of evolutionary facts.*

During the passing of the many geologic ages, which have presented millions of distinct kinds of animals, each form has had a general tendency to become more complex than the earlier, and closely related one. As the environment changed, this tendency toward an increasing complexity continued. A study of the rocks shows that the complex forms followed the simpler in regular succession. The limit of this whole process is man. However, there is no indication that would point to the seeming fact that it has "*culminated*" with him. As the term evolution implies a continuous process of unfolding from simpler to more complex forms, there is no reason to doubt that animal life will reach a much higher state than is presented in the present so-called civilized man. As pointed out in Chapter VI, we cannot even surmise what this form may be. Whether this being will be a more perfect man possessing the general characteristics of the present human family, or whether he will be one of an entirely different order from the present, is purely a matter of conjecture.

The question whether or not man should be considered in the general scale of animal life has been the cause of controversy for many years. He who wishes to decide this query for himself should first make a study of the general classification of the Animal Kingdom, giving special consideration to the structural variations, and to the relationships within each group. The questions would then naturally arise as to whether or not these variations and relationships are common in man, and, if so, whether or not they conform to the laws which govern the lower animals. Such a study will reveal the fact that the natural development of man is parallel with the general transformations which both plants and animals are undergoing. It is with this phase of the subject that this and the following chapters deal.

In order to understand the general relationships which exist between "*man's living relatives*," it is necessary to begin with the simplest form of living matter and proceed, step by step, up the scale of animal life. Altho the following discussion of relationships is greatly abbreviated, it should give a fair suggestion of the intimate kinship which an extensive presentation would more conclusively establish. As the many animal groups, from the lowest to the highest, are presented, the reader should gain an impression of the increasing scale of complexity. He should also be able to see how the ***present-day forms***, thru their ***geologic ancestors***, are indeed ***man's relatives***.

The Cell and the Organ

The Unit of Animal Structure.—Each subdivision of a living body is composed of minute particles of protoplasm called *cells*. This is true of plants as well as of animals. Just as a piece of sandstone is made up of tiny grains of sand, the body of a man, a frog, a worm, or a plant is composed of cells. No one knows the *exact* composition of protoplasm. Since it is the only substance that possesses life, the cell may be called the ***unit of structure*** of any living being. All the various tissues are built up of aggregations of these cells bound together in a compact form. Some animals are composed of but one cell, others of only a few, while still others have countless millions of these units of structure in their make-up. Where the animal is multicellular—although each cell is in reality an individual living thing within itself—all these units work in harmony toward the common end.

As a more detailed consideration of cells is reserved for Chapter XIV, a very elementary discussion is all that will be presented at this point. The word "cell," as used outside of biology, means a small cavity or an empty space. It is obvious, therefore, that the word is a misnomer, since a ***biologic cell*** would not come under that definition. Hooke, an Englishman, was the first to use the term "cell" when he observed them in a thin slice of cork. For a long time, the interest of the biologic investigators was centered upon the walls of the cells and not upon their contents, as they supposed the wall to be the essential feature. For that reason, then, the term came into general use.

Instead of being an empty space, a biologic cell is composed of many parts. By definition, ***a cell is a mass of proto-***

plasm containing a nucleus (Fig. 69). Outside the nucleus is a viscous substance called cytoplasm, while on the inside may be found many different structures which are so small that the most powerful microscope fails to reveal all of the secrets that are hidden therein. The cell, as a whole, is surrounded by a thin membrane, the cell-wall. Thus, it will be seen that a typical cell is composed of many distinct parts with varying func-

FIG. 35. Muscular tissue. 1. Nuclei. 2. Muscle fibers.

tions. The cell-wall holds the cell in shape; the cytoplasm is largely concerned in the absorption and assimilation of food; the nucleus seems to control the process of reproduction, and thus the transference of parental characteristics to the offspring.

Organs.—When we consider the many processes necessary for the maintenance of life, we often wonder how our bodies can accomplish all of them at the same time. We then note that certain parts of the body have been set aside for their own particular tasks. While our food is being digested, our eyes direct us to our work, our ears warn us of approaching danger, and our nervous system supervises our thoughts as well as directs the muscles which move our bodies. Altho the work carried on by a living body is very complicated, it is made much more simple by a *division of labor*. Each division that has its own peculiar task is called an *organ*. Each organ is composed of *tissues* which, in turn, are composed of cells.

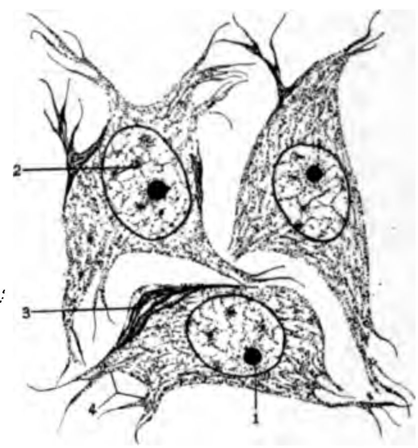


FIG. 36 (left). Epithelial cells from the lining of the mouth.
FIG. 37 (right). Nerve cells from the spinal cord of the frog. 1. Nucleolus. 2. Chromatin network. 3. Connective tissue fibrils. 4. Dendrites, shown at their beginning.

The tissues and cells are not the same in each of our specialized organs. The cells of our muscular tissue (Fig. 35) are more or less elongated and flattened. The muscle fibers, which can contract quickly and with great force, are composed of bundles of these muscle cells bound together with connective tissue. The cells of the connective and supporting tissue are irregular in shape and find their function in binding together the cells of other tissues. The epithelial cells (Fig. 36) form a soft covering for the body. They compose the lining of the nose, the mouth, and the cavities of the body as well. The most wonderful of the specialized cells are those which make up the brain and the nervous system (Fig. 37). They are able to receive stimuli, and to transmit them to other cells. They stimulate the cells of the other tissues to action; they receive impressions from the outside world thru the sense organs, and carry them to the brain. The nerve cells are extremely irregular in shape; but the general rule of cell structure applies to them, as it does in the case of other cells. Nerve cells are composed of a central mass with its nucleus, from which are given off many protoplasmic branches containing the nerve fibers. It is these fibers that compose the true "nerve." The cells which are set aside for reproduction are usually much more regular in shape than the other kinds of cells, and also, as a rule, much larger.

No one cell of a multicellular animal can live, multiply and develop indefinitely if isolated. It forms an integral part of the tissue in which it is located, and must be associated with its fellows in order to carry out its life functions. There is, then, a real interdependence between all the tissues and organs of a complex living being. The organs of digestion, respiration, and circulation are dependent upon the nervous system to keep them in action. The cells of the muscles and bones are dependent upon the blood for food and oxygen. In spite of the very complicated processes necessary for the maintenance of life in a highly organized being, we find that practically all of them can be accomplished by a single cell. However, this wonderful cell must be that of a unicellular organism for there is not a single cell in the body of a higher animal that could master the feat of "life making" alone. The one-celled animals which can carry on these life processes are confined to only one great group—the Protozoa.

Primitive Forms

Phylum (Tribe) Protozoa (Gr. protos, first; zoön, life).—Since classification means the grouping of animals according to color, structure, habits, and other characteristics which are common to them, all *one-celled* animals have been placed under one Phylum, *Protozoa.* As a type of the lowest form of Protozoa, the amœba (Fig. 38) will be considered. This simple bit of living protoplasm may be found on the decayed leaves and on the scum in pools of stagnant water. Upon examining such water with the microscope, many forms of life may be seen racing to and fro; but, sluggishly creeping along

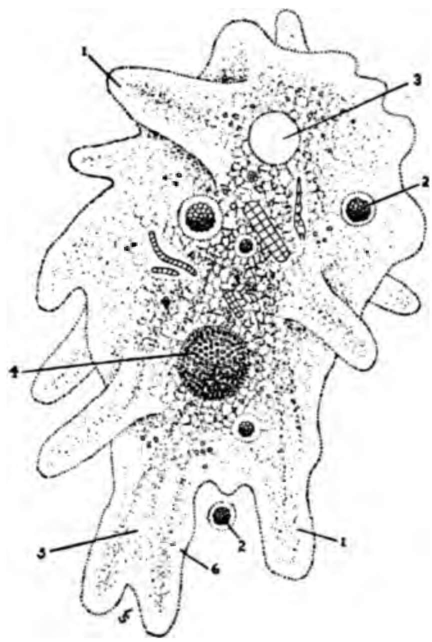


FIG. 38. *Amœba proteus.* One of the lowest forms of unicellular animals. 1. Pseudopodia (false feet). 2. Food vacuole. 3. Contractile vacuole. 4. Nucleus. 5. Endosarc. 6. Ectosarc.

the bottom, may be seen the tiny amœba. It crawls by constantly changing its form and by pushing out tiny projections of protoplasm called pseudopodia (false feet). The remainder of the protoplasm, including the nucleus, gradually flows into the foot-like projection until the entire animal has been moved. The food is also taken in by these movements. Pseudopodia are sent out around the particle of food, which is soon engulfed. The food is then digested by some mineral acid in the protoplasm. Thereupon, the food is changed into new protoplasm and thus becomes a part of the animal. Respiration is probably carried on by osmosis of the oxygen thru the delicate membrane or cell-wall; carbon dioxide is given up in return. Waste products which are formed within the cell are passed out thru the contractile vacuole (3, Fig. 38). This

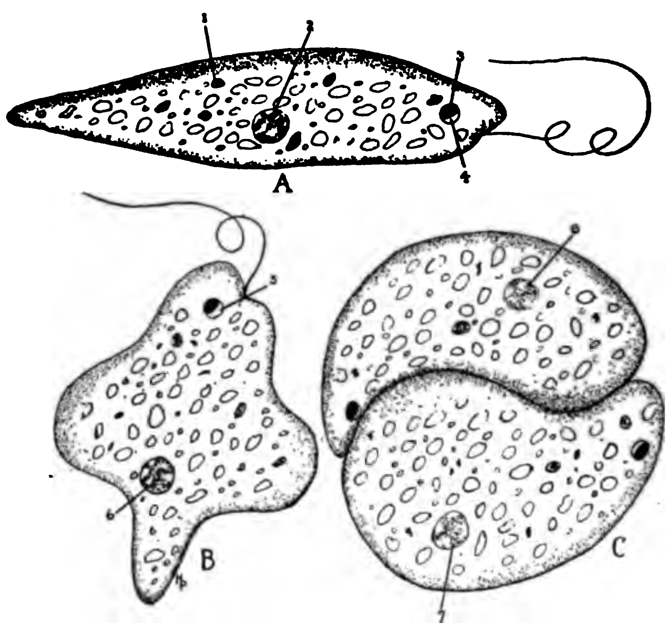


FIG. 39. *Euglena viridis.* A unicellular animal showing a higher specialization of parts than exists in the amoeba. A, B. Free-swimming in different stages of contraction. C. Dividing. 1. Chlorophyll. 2, 6, 7, 8. Nucleus. 3. Pigment spots. 4, 5. Contractile vacuole.

organ may be easily recognized by its pulsating movements. As the amœba feeds, anabolism (the change of food material into protoplasm) exceeds katabolism (the breaking down of protoplasm), and, thus, the animal increases in size. This continues until the cell becomes so large that the surface of the cell-wall is not great enough to supply the greater volume of cytoplasm with food and oxygen. The division which then takes place is an example of the most primitive form of reproduction. It is interesting to note that Kühn (1915) contends that the amœba divides mitotically (See Chapter XIV), and not by simple, or direct, cell division as is usually supposed. It may be clearly observed from this brief consideration that the one-celled organisms can perform practically all the activities that are carried on in a very complex animal. Since, in this case, a division of labor is an impossibility, the single cell must take in food, absorb oxygen, change food into protoplasm, excrete waste material and carry on the process of reproduction.

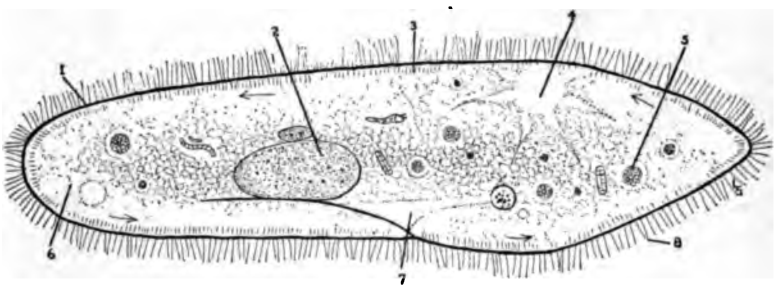


FIG. 40. *Paramecium caudatum.* A type of more highly specialized protozoa. 1. Cuticle. 2. Nucleus. 3. Ectosarc. 4. Contractile vacuole. 5. Food vacuole. 6. Endosarc. 7. Oral groove. 8. Cilia.

Altho the other common protozoa are composed of only one cell, many of them show more signs of *specialization* than does the amœba. There is usually a *definite portion of the cell* set aside to perform certain functions. The euglena (Fig. 39), for example, is of a more definite form than the amœba. Although it has a funnel-shaped pharynx, it is questionable if it functions in the taking in of food—the food being manufactured as in green plants, namely, by chlorophyll action. From this "mouth" extends a long hair-like fiber which, by its vibrations, pulls the animal thru the water. It is, furthermore, interesting to note that in the anterior end of the cell may be found a red spot that is sensitive to light. This is called the eye-spot and is considered one of the *most primitive of specialized organs of sight*. However, it must not be thought that the euglena has a power of vision in the usual sense of the term, as the eye-spot is not sufficiently developed for distinct images to be formed. The eye-spot of the euglena is very significant from an evolutionary standpoint. It would be interesting to trace the development of the eye from this primitive type thru the animal scale up to the well developed eye of man.

Certain organs of specialization may also be observed in the paramecia (Fig. 40), but with certain modifications. Locomotion is accomplished by means of short cilia which cover the surface of the body and line the gullet. These cilia propel the paramecium thru the water by their waving movements and also drive the animal's prey into the gullet which enters the side of the body near the anterior end. The method of reproduction of the paramecium is somewhat more complicated than that of the amœba or euglena and is interesting in that it suggests sexual reproduction in higher forms. Under ordinary conditions, a paramecium undergoes a process known as conjugation before division. In brief, the essential features of conjugation are as follows: When two individuals reach a certain size, they swim along together (as two boats locked side by side) and become completely united. Each paramecium possesses two nuclei, the macronucleus (the larger) and the micronucleus (the smaller). After the body walls of the two conjugants are fused and a protoplasmic bridge is formed between them, the micronucleus of each paramecium (after going thru certain complicated changes) passes over and unites with the macronucleus of the other. The two individuals then separate and after certain other processes take place, divide twice, transversely. Thus, each ex-conjugant forms four daughter paramecia. These young paramecia feed until they grow large, and then the above process is repeated.

The significance of the conjugation of the paramecia and other unicellular forms has been the subject of much controversy. Maupas and others considered it a *rejuvenating process*. That is, it was claimed that the organisms which had been exhausted by a series of divisions regained their vitality thru conjugation, thus making it possible to continue their life and the life of the race. Examples are easily cited where conjugation is highly suggestive of sexual reproduction in higher forms, but the homology, if there be any, between the two processes cannot be definitely stated. The recent works of Jennings, Woodruff, and others conclusively show that conjugation in the protozoa *is not essential to the maintenance of the race.* Whatever significance may be attached to the process of conjugation, it is, nevertheless, very suggestive of the beginning of a higher order in which reproduction is brought about by the mating of two individuals.

CHAPTER VIII

ANIMAL RELATIONSHIPS—(*Continued*)—CONNECTING LINKS BETWEEN PROTOZOA AND METAZOA

Introduction—Colonial Protozoa—Gonium—Volvox—Lower Invertebrates—Porifera—Coelenterata—Hydra—Sexual and Asexual Generations—Sea Anemone—Ctenophora—Platyhelminthes—Advancing Complexity—Nemathelminthes—Invertebrates of Uncertain Classification—Coelomata—The Body Cavity—Higher Invertebrates—Echinodermata—Annelida—Mollusca—Arthropoda.

"To be a good animal is the first requisite to success in life, and to be a nation of good animals is the first condition of national prosperity."

—*Herbert Spencer.*

Introduction.—Attention has been called to animals possessing various specialized parts, thus presenting specific cases of *physiological division of labor;* it has also been noted that such a division is present in rudimentary forms even in the unicellular animals. This could be perfected to a greater extent had such animals many cells instead of one with which to perform their functions. In like manner it would be impossible to have a division of labor among the citizens of any community unless a relatively large number of them were involved. In fact, the success of any specialized enterprise is, other factors being equal, in direct proportion to the density of the population in that vicinity. In the unicellular animal the division of labor is not a true division but, rather, much like the performance of tasks by a single family—only a division within a unit. Many cells—like many people in a community—are necessary in order to perfect a system of true division of labor.

Certain animals, which are usually considered to be unicellular forms, fail to separate wholly from each other at the time of cell division, thus forming collections of one-celled animals which are bound together in a compact community. The cells of each of these groups or collections are held together

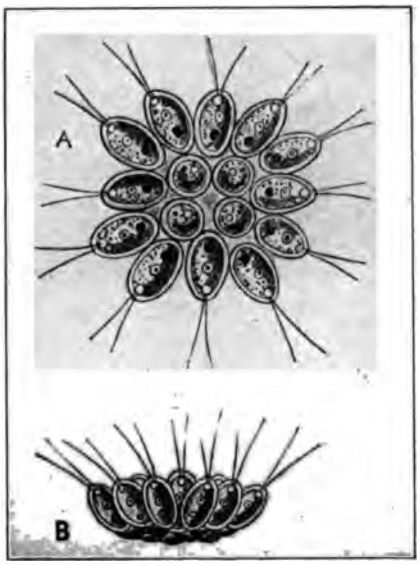


Fig. 41. Gonium. A colonial form which serves as one of the connecting links between the protozoa and the metazoa. A. Colony seen from above. B. Colony seen from the side. (From Jordan, Kellog and Heath, after Stein.)

by a gelatinous substance. Such groups are called *Colonial Protozoa.* Biologists disagree as to the nature of these animals. Some regard them as merely being *colonies* of one-celled animals with little or no interdependence. Since a definite division of labor seems to be present in some of them, it seems not at all out of place to regard them as *connecting links* between the protozoa and the metazoa (many celled animals).

Colonial Protozoa.—If the euglena (Fig. 39), which divides longitudinally, should remain attached at the posterior end and then divide again so that the four animals thus formed would remain together, and should this process be continued thru several generations, a plate of animals would soon be formed. This plate-like group of animals is actually noted in the case of certain colonial forms, particularly Gonium (Fig. 41).

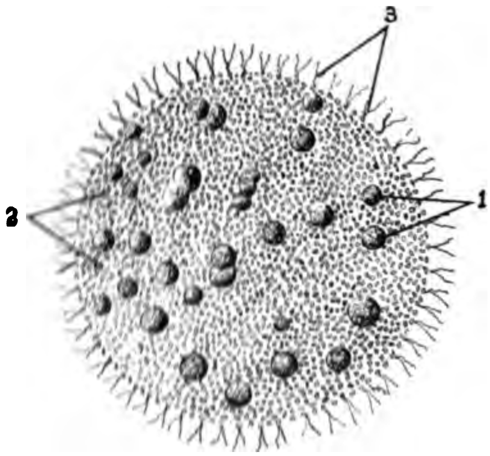


FIG. 42. Volvox. The type of colonial protozoa possessing certain characteristics of the metazoa, therefore serving as a connecting link between the unicellular and the multicellular animals. One of the earliest forms to present a marked difference between the male and the female germ cells. 1. Germ cells. 2. Somatic cells. 3. Flagella.

Each cell of the colony possesses two long protoplasmic, whiplash-like hairs which assist in collecting food and also in forcing the colony through the water. Other colonial forms, the Pandorina for instance, are formed similarly to the Gonium, but the cells are arranged in a spherical rather than a plate-like colony. This fact is significant in that it is suggestive of the mulberry, or morula, stage in the ontogeny of higher forms (See Development of Frog, Chapter V). Pandorina is of further evolutionary significance in that it seems to be the lowest form in which there is a size difference in the cells which unite to produce individuals.

A still more interesting form which is found in fresh water, and which is figured in almost all elementary textbooks, is the

Volvox (Fig. 42). This form is usually classed with the protozoa under the class *Flagellata;* but, owing to the extreme specialization of certain cells of the colony, it seems almost impossible for it to be a unicellular organism. The spherical colony is composed of many hundreds of cells, which are connected by protoplasmic material. Among this collection may be found both the somatic cells (body cells) and the germ cells (reproductive cells) which are set aside for the purpose of reproduction, as is common in the metazoa. There are two types of germ cells homologous to the sperms and eggs of the higher animals. The eggs are fertilized by the spermatozoa, and after a certain resting stage, the fertilized eggs develop into new colonies. In respect to its method of reproduction, the Volvox should be considered a metazoan.

While considering the position of the Volvox in the animal scale, Jordan and Kellogg present the following suggestions: "There is a real interdependence among the thousands of cells of the colony. The function of reproduction rests with a few particular cells, and for the perpetuation of the species there is demanded a coöperation of two distinct kinds of reproductive cells. The great majority of the cells take no part in reproduction. They can perform all the other life processes; they move the colony by lashing the water with their flagella; they take in food and assimilate it; they can feel. All the cells of the great colony, too, are intimately connected by means of protoplasmic threads. The protoplasm of one cell can mingle with that of another; food can go from cell to cell. The question whether the *Volvox* colony is a group of distinct organisms or is a single organism made up of cells among which there is a simple but obvious difference in structure and function; in other words, whether *Volvox* is a colony of one-celled animals, of Protozoa, or is a multicellular animal, one of the Metazoa (for so all the many-celled animals are called), is a difficult one to decide." In view of the many intermediate forms the gap between the protozoa and the metazoa should be considered very small.

THE SCROLL OF

PHYLA	CHARACTERISTICS OF THE PHYLA	CLASSES
I Protozoa (Gr. protos, first; zoön, animal.)	One cell. Usually microscopic. No tissues. Conjugating cells. Reproduction by division of cell—sperms and eggs rarely present. In many cases colonial.	**I Rhizopoda** (Gr. rhiza, a root; pous, foot.) **II Flagellata** **III Ciliata** **IV Sporozoa**
II Porifera (Lat. porus, a pore; ferre, to bear.)	Framework of spicules of horn-fibers which surrounds the little animal. Usually salt water. Food taken in by small lateral pores, water passes out thru the large central opening (osculum).	**I Calcarea** (Lat. calcarius, lime.) **II Hexactinellida** (Gr. hex, six; aktin, ray.) **III Demospongiæ** (Gr. demos, people; spongos, sponge.)
III Cœlenterata (Gr. koilos, hollow; enteron, intestine.)	Usually sea forms. One cavity in body serves for both digestion and circulation. Two distinct layers (ectoderm and entoderm) and a jelly-like middle layer. Stinging cells. Usually radially symmetrical (4 or 6 antimeres, or multiples of these numbers).	**I Hydrozoa** (Gr. hydra, a water serpent; zoön, animal.) **II Scyphozoa** (Gr. skuphos, cup; zoön, animal.) **III Anthozoa** (Gr. anthos, a flower; zoön, animal.)
IV Ctenophora (Gr. ktenos, of a comb; phoreo, I bear.)	Comb-like locomotor organs. Free swimming. Classification uncertain. Adhesive cells. Transparent. Bi-radially symmetrical.	I Tentaculata II Nontentaculata
V Platyhelminthes (Gr. platus, broad; helmins, an intestinal worm.)	Worm-like. Elongated and flattened, primitive nervous system, and branching excretory system. Usually parasitic. Hermaphroditic.	I Turbellaria (Lat. turbo, I disturb.) II Trematoda (Gr. trema, a pore; eidos, resemblance.) III Cestoda (Gr. kestos, a girdle; eidos, resemblance.)
VI Nemathelminthes (Gr. nema, thread; helmins, an intestinal worm.)	Unsegmented round worms, mouth and anus. Usually unisexual.	Nematoda. Digestive tract. Acanthocephala. No digestive tract.

Uncertain Classification: Nemertinea (Gr. nemertes, true) Nematomorpha. (Gr. nema, thread; morphe, form.)

ANIMAL LIFE

Characteristics of Each Class	Examples (scientific name)	(common name)
Locomotion by pseudopodia (false feet). Membrane absent or incomplete.	Amœba proteus	Amœba
Definite form. Locomotion by flagella. Pseudopodia often present.	Euglena viridis	Euglena
Mouth and arms usually present. Locomotion by cilia.	Paramecium	Paramecium
Parasitic. Reproduces by spores. Food usually taken from a host. Non-motile—at least in adult condition.	Plasmodium vivax	Malaria parasite
Skeleton of lime. Shallow water. Central cavity lined with collared cells.	Grantia	
Simple spicules of silicon (sand) and with six rays. Deep sea.	Euplectella aspergillum	Venus' flower basket
Deep sea forms with silicon spicules (not six-rayed) or of spongin or both. Highest type. Includes practically all sponges.	Euspongia	Bath sponge
Fresh water. Simple mouth part inconspicuous. No mesenteries. Reproduces both sexually and asexually (budding) and fission.	Hydra	Fresh water hydra
Cup-like. Internally, four longitudinal folds. Large jellyfish. Eight notches in margin of umbrella.	Aurelia	Jellyfish
Flower or tree-like. No jellyfish. Marine. Usually sessile and colonial. Shallow water. Reproduces both sexually and asexually (budding and fission).	Metridium Astrangia	Sea-anemone Coral
Body spherical or cylindrical; with and without tentacles.	Bolina Beroë	Sea walnuts and Comb jellies
Free-living. Ciliated ectoderm. Hermaphroditic—no body cavity.	Planaria	"Flat worms"
Parasites. Suckers. Forked intestine with arms. Ecto- or endoparasitic.	Distomum hepaticum	Liver fluke
Parasites. No mouth or alimentary canal. Segmented.	Tænia	Tapeworms
Digestive tract. No digestive tract.	Ascaris	Intestine worm

Rotifera	Bryozoa	Brachiopoda
(Lat. rota, wheel; ferro, I carry.)	(Gr. bruon, moss; zoön, animal.)	(Gr. Brachion, arm; pous, foot.)

THE SCROLL OF

PHYLA	CHARACTERISTICS OF THE PHYLA	CLASSES
VII [illegible] [illegible]	[illegible] Spiny skeleton, radial symmetry, usually five-radiate. [illegible] vascular system. Various colors [illegible] transparent. Gut [illegible] from body cavity. Sense [illegible] usually poorly developed. [illegible] tube feet.	I Asteroidea (Gr. aster, star; eidos, resemblance.)
		II Ophiuroidea (Gr. ophis, snake; oura, tail; eidos, resemblance.)
		III Echinoidea (Gr. echinos, a sea-hedgehog; eidos, resemblance.)
		IV Holothuroidea (Gr. holos, whole; thourios, rushing; eidos, resemblance.)
		V Crinoidea (Gr. krinon, a lily; eidos, resemblance.)
VIII [illegible]	[illegible] worms.	I Chætopoda (Gr. chaite, bristle; pous, foot.)
		II Hirudinea (Lat. hirudo, leech.)
IX [illegible]	[illegible] shell usually present. [illegible] Nervous system [illegible] ring [illegible]	I Lamellibranchiata
		II Scaphopoda (Gr. skaphe, boot; pous, foot.)
		III Solenogastres
		IV Gastropoda (Gr. gaster, belly; pous, foot.)
		V Cephalopoda (Gr. kephale, head; pous, foot.)
X [illegible]	[illegible] Alimentary [illegible] opening, [illegible] Jointed [illegible] exoskeleton.	I Crustacea (Lat. crusta, skin.)
		II Onychophora
		III Myriapoda
		IV Insecta

[illegible] I Aptera—Simplest insects. II Odonata—Dragon flies, [illegible] Hemiptera—True bugs, cicadas, aphids, scale insects, etc. [illegible] Lepidoptera—Moths and butterflies. X Hymenoptera—Ichneumons, ANIMAL LIFE—*Continued*

Characteristics of Each Class	Examples (scientific name)	(common name)
Five arms not distinctly marked off from the flat central disc. Possess spines.	Asterias	Starfish
Five snake-like arms distinctly marked off. Arms used in locomotion. Flattened body. No ambulacral grooves. Body not ciliated.	Ophiuridea	Brittle stars
No arms or rays, but pentamerous markings. Skeleton made of calcareous plates closely adjusted. Spines. Ambulacral appendages.	Echinus	Sea urchin
Long ovoid leathery muscular body. Contractile tentacles around mouth. No spines. Sexes usually separate. Great power of regeneration.	Cucumaria	Sea cucumber
Sea forms. Usually five branched arms. Resembles lily attached at base.	Pentacrinus	Sea lilies
Bristles (setae) for locomotion. With or without parapodia.	Lumbricus terrestris	Angleworms
Without bristles but with suckers.	Hirudo Medicinalis	Leeches
Shell composed of two valves. Bilaterally symmetrical. Without head. Hatchet foot for locomotion.	Ostrea Mya	Oyster Clam
Tooth-shaped shell. No heart, eyes, or respiratory apparatus.	Dentalium	Elephant's tusk
Worm-like. Devoid of shell and foot.	Proneomenia	
Shell usually spirally coiled. Distinct head and foot. Slugs with invisible shell.	Helix Limax	Snails Slugs
Foot divided into arms with suckers. Well developed nervous system, eyes and ears. Breathes by means of gills.	Nautilus Loligo Octopus	Nautilus Sea Squid Octopus
Chitinous cuticle of carbonate and phosphate of lime. Aquatic or modified for air-breathing.	Cambarus	Crayfish
Excretory organs segmentally arranged, stump-like legs, simple eyes. Connects segmented worms and insects.	Peripatus	
Distinct head, one pair tentacles, and one pair mandibles. Body segments, leg-like appendages, trachea, excretory organs.	Chilopoda	Millipedes and Centipedes
Head distinct. Pair of antennæ and mandibles. Two pair of maxillæ. Labium. Trachea. Spiracles.	See orders below	See orders below

damsel flies. III Isoptera—White ants. IV Orthoptera—Cockroaches, locusts, grass-
VI Neuroptera—Nerve-winged insects. VII Coleoptera—Beetles. VIII Diptera—Two-
gall-flies, wasps, bees, and ants.

THE SCROLL OF

PHYLA	CHARACTERISTICS OF THE PHYLA	CLASSES
XI Chordata (Lat. chordatus, possessing a cord.)	Skeletal axis or notochord, paired gill slits, central nerve cord dorsal to alimentary canal. Neurocœle.	I Urochorda (Tunicata.)
		II Hemichorda
		III Cephalochorda (Gr. kephale, head; chorde, cord.)
		IV Vertebrata (Lat. vertebratus, joints.)
Sub-phylum Vertebrata.	Internal segmentation. Vertebral column. Skin, many-layered epidermis. Gill slits in adult or embryonic condition.	Class I Cyclostomata
		Class II Elasmobranchii
		Class III Pisces
		Class IV Amphibians
		Class V Reptiles
		Class VI Birds
		Class VII Mammals

ANIMAL LIFE—*Continued*

Characteristics of Each Class	Examples (scientific name)	(common name)
Tunic of cellulose ($C_6H_{10}O_5$); mantle and incurrent and excurrent opening.	Molgula Salpa, etc.	Sea-squirts
Worm-like. Burrows in mud. Proboscis in collar-like acorn in its cup. Paired gill slits.	Balanoglossus	Acorn-tongue worm
Fish-like body. Pointed at both ends. Atrial opening. No skull, vertebræ, brain, or heart. Primitive kidneys (nephridia) and notochord present.	Amphioxus lanceolatus	Amphioxus
(See below under characteristics of sub-phylum.)	See classes below	See classes below
Eel-like. Without jaws and lateral paired fins, no vertebral column except cartilaginous; circular rasping and sucking mouth. Straight intestine.	Bdellostoma Myxine Petromyzon	Hagfish Lamprey eels
Paired fins; gill arches; no membranous bones, air bladder or true scales; spiral valve.	Squalus Raji	Dogfish sharks Rays
Vertebral column; cranium and well developed skeleton. True scales usually present.		See orders below
Cold-blooded; scaleless skin; lung breathers in adult life; limbs usually present.		See orders below
Cold-blooded; lung breathers; usually scaly (see characteristics of orders.)		See orders below
Warm-blooded; normal temperature higher than that of any other group; egg layers (oviparous); body covered with feathers; anterior limbs appear as wings.		See orders below
Warm-blooded; usually bear young alive (viviparous); mammary glands; body covered with hair, but reduced in some forms.		See orders below

CLASSIFICATION OF FISHES

Order I. *The Ganoids.* Once abundant, now almost extinct. Plate like scales. Examples; bow fin, sturgeons, gars.
Order II. *The Teleosts.* The common food fishes, composing over 90% of all living fishes. Gills protected by an operculum. Examples: perch, trout, bass, codfish.
Order III. *The Dipnoi.* Swim bladder used as lungs, thus commonly spoken of as *lung fishes.* Certain other amphibian characteristics. Inhabit marshes and lakes of Central Africa, South America and Australia.

CLASSIFICATION OF AMPHIBIA

Order I. *Apoda.* Limbless, wormlike forms inhabiting tropical and sub-tropical regions.
Order II. *Urodela.* Tailed amphibians with rudimentary or poorly developed legs. Examples: salamander, newt, mud puppy.
Order III. *Anura.* Abundant, undergo metamorphosis, gills in larval stage, lungs in adult. Examples: frogs and toads.

CLASSIFICATION OF REPTILES

Order I. *Chelonia.* Broad, flat, double-skeleton forms, toothless. Examples: turtles and tortoises.
Order II. *Lacertilia.* A rough, scaly form which breathes by lungs. Well developed legs. Examples: lizards, horned toads, gila monsters.
Order III. *Ophidia.* An elongated, limbless form covered with small scales. Examples: snakes of various kinds.
Order IV. *Crocodilia.* Inhabit marshes. Body well-proportioned, four well-developed legs, long tail, heavy bony scales especially prominent on dorsal side. Examples: alligators and crocodiles.

CLASSIFICATION OF BIRDS

Order I. *Running Birds.* Rudimentary or poorly developed wings. Examples: rheas, cassowary, ostrich.
Order II. *Passeres.* Three toes in front, one behind adapted for perching. Examples: lark, swallow, thrush, sparrow.
Order III. *Gallinæ.* Well distributed, feet adapted for scratching. Examples: jungle fowls from which the domestic fowls have developed, pheasants, quail.
Order IV. *Raptores.* Hooked-bill, strong, well-developed claws adapted for grasping. Spoken of as birds of prey. Examples: hawk, owl, etc.
Order V. *Grallatores.* Legs, neck and beak very long, adapted for wading and fishing. Examples: snipes, herons and cranes.
Order VI. *Natatores.* Legs short, and toes webbed, adapted for swimming and diving. Examples: ducks, swans and albatross.
Order VII. *Columbinae.* Characteristics familiar. Examples: doves and pigeons.
Order VIII. *Pici.* Toes arranged for climbing and clinging to upright perch. Two toes pointed forward, two back. Example: woodpeckers.
Order IX. *Psittaci.* Hooked beak, fleshy tongue and strong toes arranged for perching. Example: parrots.
Order X. *Coccyges.* Powerful beak, toes arranged for climbing. Examples: cuckoo and kingfisher.
Order XI. *Macrochires.* Long-pointed wings, very active. Examples: humming birds and swifts.

CLASSIFICATION OF MAMMALS

Order I. *Edentata.* Teeth without enamel and absent from anterior part of jaw. Very primitive form of mammal. Examples: armadillo, sloth and ant eaters.
Order II. *Rodentia.* With one or in a few cases two pair of sharp chisel shape incisors in upper jaw. Examples: pocket gopher, guinea pig, mice, rabbits, porcupine, beavers and squirrel.
Order III. *Cetacea.* Marine form. Examples: whale, porpoise.
Order IV. *Ungulata.* Grinding teeth, hoofed animals, some with one (horse, rhinoceros), other with two toes (ox, pig, sheep and deer).
Order V. *Carnivora.* Prominent claws, projecting canine teeth, incisors small, premolars adapted for cutting flesh. Examples: fox, skunk, dog, cat, bear, lion, sea lion, seal, walrus, etc.
Order VI. *Insectivora.* Examples: mole and hedgehog.
Order VII. *Chiroptera.* Teeth pointed, claws fairly well developed, four limbs modified for flight. Example: bat.
Order VIII. *Primates.* More or less upright position, large brain, claws modified to nails, hands adapted for grasping. Examples: monkeys, apes and man.
Classification of vertebrates modified from Hunter and others.

The Lower Invertebrates

Phylum Porifera (Lat. porus, a pore; ferre, to bear).—As this Phylum, together with the succeeding phyla of the Animal Kingdom, will be taken up very briefly—representative specimens only from each one being considered—the reader should make constant use of the Scroll of Animal Life (Chart II) in order to gain a more comprehensive knowledge.

With the sponges, we pass one step higher up the scale of life. Although they possess many characteristics of the higher forms, many of their life functions are carried on in simple protozoan fashion. They are stationary animals and are without definite shape. The water bearing the food particles is taken in thru minute pores (hence the name, Porifera) in the body wall and passes into the central cavity and thence out thru the opening at the top, the osculum. The food is digested and absorbed by the same method as that employed by the colonial protozoa. In fact, it is quite probable that certain protozoa (Proterospongia) were the ancestors of the early forms of sponges. The sponge has no organs of digestion, but, as noted above, digestion is intercellular. Oxygen is obtained from the water by osmosis. The sponge shows more advancement than many of the earlier forms. The cells of the body are arranged in three layers, the ectoderm, or outer layer; the entoderm, or inner layer; and the mesoderm, or middle layer. From the cells of the mesoderm arise fine needles or spicules made of lime and silica, which represent a primitive form of skeletal structure.

Reproduction in the sponge is accomplished by two methods; namely, by budding, and by the union of the sperm and the egg as considered in the case of the Volvox. The latter method is spoken of as sexual, while the former is the asexual method of reproduction. Both the male and the female germ cells are formed in the mesoderm, and, after uniting in the process of fertilization, develop into a ciliated larva. This new individual swims about, takes food, and lives a free and active life. This suggests the adult stage in certain protozoa. The young sponge later attaches itself to some object by its "mouth," and while it assumes a cylindrical shape, an opening —the future osculum—appears at the free end and the pores begin to open in its walls. Thus, the free-swimming colonial protozoan-like animal becomes a stationary adult sponge. In the asexual method of reproduction, buds are set free to later develop into complete adult sponges. Sometimes the buds are retained attached to the parent sponge, thus forming an ensemblage of individuals on one parent stalk.

Phylum Cœlenterata (*Gr. koilos, hollow; enteron, intestine*).—Until the present discussion, no animal has been considered which possesses a food tube and a body cavity. True, the sponge was found to have a central cavity but it merely

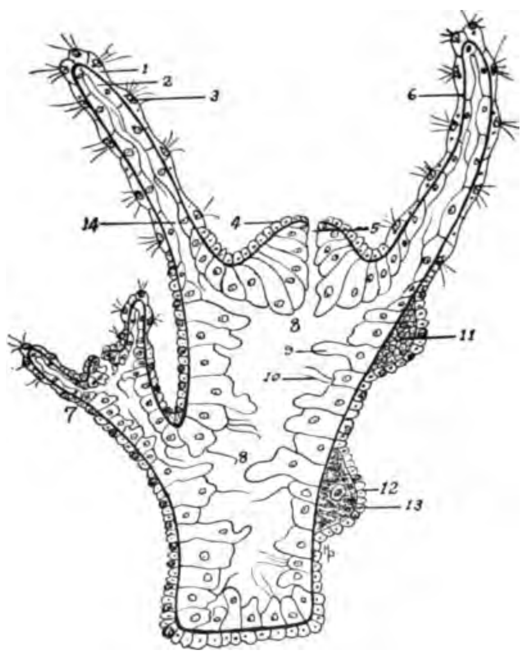


FIG. 43. Longitudinal section of a hydra (semi-diagrammatic). 1. Ectoderm. 2. Entoderm. 3. Nematocysts (stinging cells). 4. Hypostome. 5. Mouth. 6. Mesoglea. 7. Bud. 8. Gastro-vascular. 9. Entodermal cells. 10. Flagella. 11. Male germ cells. 12. Ovary bearing a female germ cell. (13). 14. Cavity of tentacle.

served as a passageway for outgoing currents of water and not as a digestive cavity. The cells themselves perform the functions of digestion and assimilation. In the hydra (Fig. 43), one of the simplest of the cœlenterates, there is found a mouth opening into a primitive digestive cavity. This cavity is lined with irregularly shaped cells, which have the power of sending out pseudopodia to grasp and ingest the partially digested food. The food then passes from cell to cell by osmosis. With respect to the division of the body wall, the hydra seems to be less highly developed than the sponge. In place of the conspicuous middle layer (mesoderm) of the sponges, we find only a thin layer of non-cellular jelly-like substance, the mesoglea (6, Fig. 43). As for offense and defense, and the ability to capture food, the hydra far surpasses any of the earlier forms. In the first place, it is not permanently attached but can release itself from its base and move about on any submarine surface by a kind of somersault movement. Or, if it releases itself entirely, the currents in the water will carry it to some new location. Thus, the hydra is not forced to rely entirely upon one position for food. If the supply is inadequate, it can move to another environment, while a sponge would be forced to remain and perhaps starve. Around the mouth of the hydra are a number of arms (the tentacles) which are supplied with stinging cells (nematocysts). These cells are used in defense, and also in capturing certain prey. After this prey has been paralyzed or killed by the sting of the nematocysts, it is forced thru the primitive mouth-opening (5, Fig. 43) by means of the tentacles.

In regard to sexual reproduction, the hydra resembles the sponges and the volvox; however, there is a considerable modification. Asexually, the hydra reproduces by fission (division) as in certain protozoa, and by budding. The buds grow from the sides of the body wall (7, Fig. 43) and remain attached to the parent until the tentacles and the mouth are formed. The eggs and the spermatozoa are formed from the ectodermal cells and are shed into the surrounding water where fertilization takes place.

Many splendid examples of specialization and division of labor might be collected from the higher Cœlenterates, but a summary discussion of one of the more complex will suffice. The colonial sea form, the Obelia, will serve as the type. This plant-like animal possesses a basal stem from which are given off upright branches known as hydroid colonies. Upon these branches may be found flower-like buds called polyps. Some of these buds bear a striking resemblance to the adult hydra, and are employed entirely in obtaining food. Other polyps are set aside entirely for the purpose of reproduction. The buds which are given off from these polyps are called medusa-buds. They grow directly into a jellyfish—the medusa. This is known as the *asexual generation.* The jelly fish matures and produces sperms and eggs which unite to form a ciliated protozoan-like larva. This is known as the *sexual generation.*

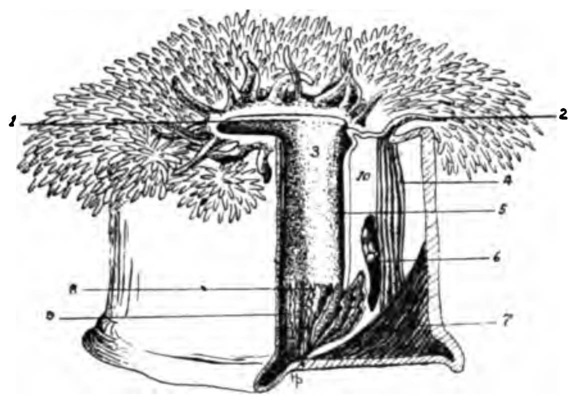


Fig. 44. Sea-anemone (diagrammatic). Dissected to show the single gastro-vascular cavity and the mesenteries. 1. Mouth. 2. Tentacle. 3. Gullet. 4. Longitudinal muscle. 5. Siphonoglyphe. 6. Gonads. 7. Parietal muscle. 8. Mesentery filaments. 9. Secondary mesentery. 10. Primary mesentery.

This free-swimming larva, after passing thru certain stages of development, forms a new hydroid colony. The process is then repeated for each new generation. It is readily seen that during the life cycle the animal must pass thru two distinct generations—asexual and sexual. This complete process is spoken of as the alternation of generations and is very common in the Cœlenterates.

The Cœlenterates present a broad range of animal structure. The increasing complexity might be followed, step by step, until fairly complex forms are reached. The sea-anemone (Fig. 44), for example, shows an increase in complexity of the internal structure. The gullet opens into a large space which extends radially between mesenteries (partitions). The cavity between the mesenteries into which the food passes possesses many subdivisions showing a marked increase in complexity.

The Cœlenterates possess no distinct alimentary canal separate from the body cavity, the gastrovascular (digestive-circulatory) space serving alike for digestion and circulation. This cavity has only one opening, which serves both as mouth and anus. A definite nerve ganglion, excretory system, and circulatory system are lacking in this Phylum.

Phylum Platyhelminthes (Gr. platus, broad; helmins, an intestinal worm).—The free-living flatworms (Planarian Type) possess an alimentary cavity, but in a very primitive condition. This cavity presents various branches (suggestive of certain Cœlenterates), and has only one opening, the undigested material being ejected thru this mouth-like opening. The excretory system, however, shows a marked advance over that of the other forms we have considered. This system is composed of many ramifying tubules which connect with larger tubes and empty the waste products on the outside of the body. The small tubes terminate with a cell (flame cell) possessing a single flickering cilium which keeps the fluid contents of the tube in motion. The nervous system consists of a bi-lobed ganglion at the anterior end of the body, and two nerve cords extending one along each side. From the brain, nerve fibers pass to the primitive eyes and to the other parts of the anterior end of the body. Many of the worms are hermaphroditic; that is, each individual possesses both male and female organs,—which fact is significant from the standpoint of evolution. This fact, together with the fact that definitely specialized organs are present in these worms, indicates that the Platyhelminthes mark a decided advance over the Cœlenterata.

Phylum Nemathelminthes (Gr. nema, thread; helmins, an intestinal worm).—Many of the other worms, particularly those of Phylum Nemathelminthes, have lost their evolutionary significance thru their parasitic habits. This applies also, in part, to the Phylum Platyhelminthes, the flatworms (See the Scroll of Animal Life—Phyla V and VI). The worms that are classed under the Phylum Nemathelminthes are long and slender and usually rather cylindrical in cross section. The common vinegar eel is an excellent example of the Nemathelminthes. Others of these worms are dangerous parasites, living in the intestines of man and various other animals. Some of them attain a length of nearly a foot. The disease called trichinosis is caused by minute Nemathelminthes, Trichinella spiralis, being embedded in the muscular tissues. Altho these worms have lost their evolutionary significance, one fact stands out as notable. In them, we find for the first time a definite division of sexes—male and female being separate individuals.

Invertebrates of Uncertain Classification.—There are several groups of lower invertebrates that most zoölogists fail to agree upon regarding their definite classification. Most of these are marine types, while a few are found in fresh water. Some are parasitic. In view of the uncertainty of their classification and relation to other forms, it is impractical to treat of them further in this brief discussion.

Cœlomata

In the foregoing discussions we have traced—tho superficially—the development of structural complexity from the one-celled, organless animal to forms having a digestive tract (altho primitive), definite nervous and excretory systems, and rudiments of eyes. Space would not permit even a brief consideration of the developmental relationships between each group, but the increasing complexity should have been made evident. A constant use of the Scroll of Animal Life (Chart II) will fill in many of the gaps that occur in the text.

The appearance of certain distinguishing characters are so significant that they warrant a brief consideration at this point. It will be remembered that the body wall of the sponges and the Cœlenterates is composed of two layers separated by a jelly-like structure. Altho the term mesoderm is applied to this middle layer, it is composed in the two forms mentioned of only wandering cells from the ectoderm. However, its relationship to the true mesoderm of the higher animals is sug-

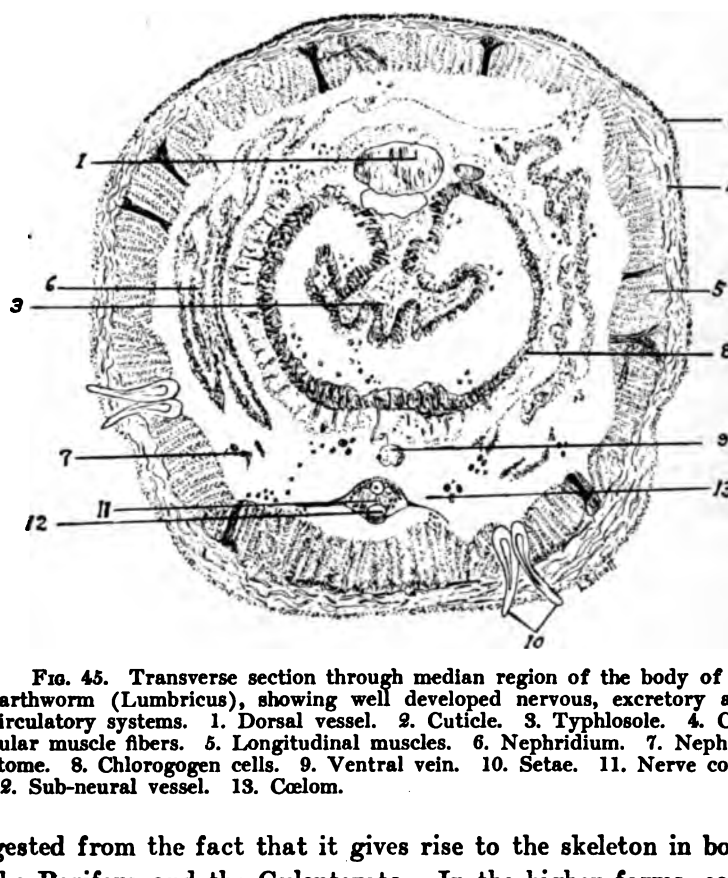


Fig. 45. Transverse section through median region of the body of an earthworm (Lumbricus), showing well developed nervous, excretory and circulatory systems. 1. Dorsal vessel. 2. Cuticle. 3. Typhlosole. 4. Circular muscle fibers. 5. Longitudinal muscles. 6. Nephridium. 7. Nephrostome. 8. Chlorogogen cells. 9. Ventral vein. 10. Setae. 11. Nerve cord. 12. Sub-neural vessel. 13. Cœlom.

gested from the fact that it gives rise to the skeleton in both the Porifera and the Cœlenterata. In the higher forms, each of the three body layers plays a distinct part in the formation of the various organs of the body. It was further noted that the body of the Cœlenterates (hydra as a type) possesses only one cavity—the digestive cavity (8, Fig. 43). A cross section of an earthworm, on the other hand, suggests a small tube inside a large one, thus showing two distinct cavities within the body wall of the animal (Fig. 45). This cavity within the intestine is the digestive cavity; the one between the body wall and the inner tube is the *body cavity*, or *cœlom*. Technically, the terms *cœlom* and *body cavity* are not always synonymous; but this should not be confusing. The cœlom is found either in the embryo or adult stage in all forms of life *from the earthworm to man*, inclusive. Most zoölogists consider the cœlom of sufficient importance to be the basis upon which to divide all metazoa into two classes: acœlomata (without) and cœlomata (with a cœlom). It is, as yet, uncertain whether or not the Platyhelminthes (flatworms) and the Nemathelminthes (roundworms) possess a cœlom. This places them as connecting links between the acœlomata and cœlomata.

The coelom is usually defined as "A cavity in the mesoderm lined by an epithelium; into it the excretory organs open, and from its walls the reproductive cells originate." The presence of a cœlom gives a better opportunity for the development of organs of nutrition, excretion, and reproduction. It, then, is really a dividing mark between the lower and the higher forms of life.

Higher Invertebrates

Phylum Echinodermata (Gr. echinos, a sea-hedgehog; derma, skin).—There are five kinds of echinodermata; namely, starfishes, brittlestars, sea-urchins, sea-cucumbers, and sea-lilies. The general structural features of these salt water forms show an advancement over the earlier forms.

Phylum Annelida (Lat. annellus, a little ring).—While considering the earthworm (Fig. 45) as a type of a more highly developed animal, attention should be called to the fact that the nervous and the circulatory systems are fairly well developed, and that the digestive tract has a posterior opening for the discharge of body waste, and that the excretory system is developed into specific organs called nephridia (kidneys).

Phylum Mollusca (Lat. mollis, soft).—The fact that the higher molluscs possess a well developed nervous system with a more centralized (tho primitive) brain, and (with few

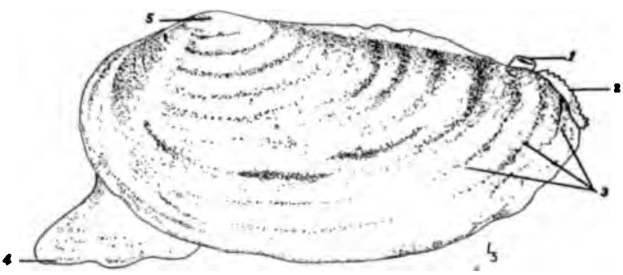


Fig. 46. External features of a clam (*Anodonta*). Possesses highly developed nervous and circulatory systems. 1. Dorsal siphon. 2. Ventral siphon. 3. Lines of growth. 4. Foot protruded. 5. Umbo.

exceptions) a three chambered heart, should give this group a prominent place in the scale of animal life. The best known representatives of this group are the oysters and the clams (Fig. 46).

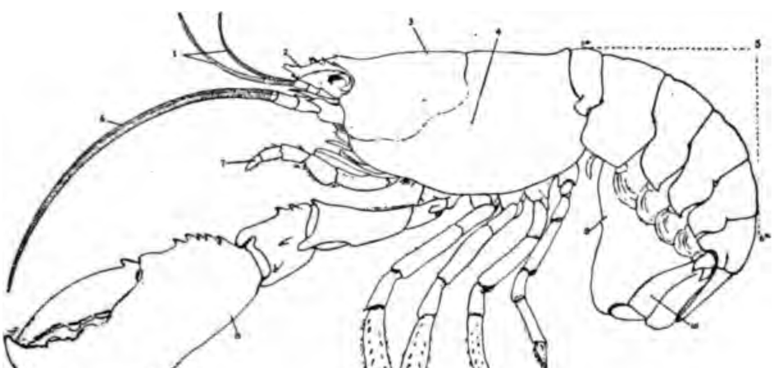


Fig. 47. The North American lobster. 1. Antennule. 2. Rostrum. 3. Cephalothorax. 4. Gill-cover. 5. Abdominal segments. 6. Antennae. 7. Maxilliped. 8. First leg. 9. Abdomen. 10. Uropod.

Phylum Arthropoda (Gr. arthron, a joint; pous, foot).—While considering the advancing complexity of the Phylum Arthropoda (See Scroll of Animal Life), Linville and Kelly state: "Its advance over the Annulata (Annelida) consists in the tendency of somites (segments) to be fewer and more definite in number. The somites are grouped in two or three regions; in certain regions the somites are fused, an indication of still greater differentiation. All the appendages are segmented. The dorsal blood-vessel is more differentiated than other parts of the circulatory system, and in some classes it is a clearly defined one-chambered heart. Sense-organs, especially eyes, reach a condition of great complexity in comparison with that found in the lower phyla." The crayfishes, lobsters (Fig. 47), the centipedes, and the insects are members of the Phylum Arthropoda.

CHAPTER IX

ANIMAL RELATIONSHIPS—(*Continued*)—HIGHER TYPES OF ANIMAL LIFE

Probable Connecting Links between the Invertebrates and Vertebrates—Primitive Chordata—Urochorda—Hemichorda—Cephalochorda—Lower Vertebrates—The Fishes—Exoskeleton—Endoskeleton—True Vertebrates—Amphibia—Reptiles—Birds—Mammals—Primates—Man—Conclusion—Ancestral Tree.

"The nature of the universe is the nature of things that are. Now, things that are have kinship with things that are from the beginning. Further, this nature is styled Truth: and it is the first cause of all that is true."

—*Marcus Aurelius.*

The terms invertebrates and vertebrates are usually considered sufficient to include every species of animal. Indeed, this was the idea of the early zoölogists. In more recent years, however, animals have been found which possess characteristics of both groups and thus cannot be placed with either. In these forms, instead of the vertebral column, there is found an elastic gelatinous rod (the notochord). In order to include this group of animals, the term *chordata* was adopted. This group includes all animals that possess *gill slits* either in adult or embryonic stages, a nervous system dorsal to the intestine, and a notochord. One of the lowest forms of chordata is the marine acorn-tongue worm (Balanoglossus-Hemichorda) (Fig. 48) which is distinctly worm-like in appearance, with a ventral as well as a dorsal nerve chord. The dorsal one, however, is somewhat better defined than the ventral—suggesting chordate characteristics. This worm-like animal possesses a notochord-like structure and definite gill openings.

Although the interesting creature shown in Figure 49 would never suggest a vertebrate, the zoölogists consider it a valuable connecting link. The larva of the sea-squirt possesses the

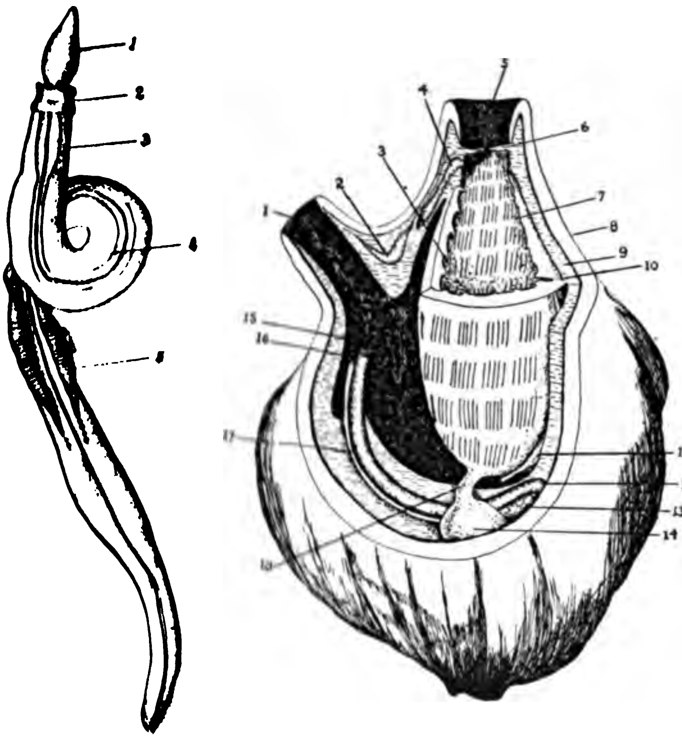


FIG. 49. Balanoglossus (left) acorn-tongue worm possessing certain characteristics which mark it as one of the connecting links between the vertebrates and the invertebrates. 1. Proboscis. 2. Collar. 3. Branchial region. 4. Genital ridge. 5. Hepatic prominences.

FIG. 50. Sea squirt (*Molgula*) (right). 1. Atriopore. 2. Neural gland. 3. Dorsal lamina. 4. Hypophyseal duct. 5. Mouth. 6. Velum. 7. Sub-divided pharyngeal clefts. 8. Tunic. 9. Mantle. 10. Endostyle. 11. Heart. 12. Intestine. 13. Gonad. 14. Stomach. 15. Atrial cavity. 16. Anus. 17. Duct of gonad. 18. Oesophagus. (Semi-diagrammatic from preserved specimen after Newman.)

characteristic dorsal neural tube, gill slits, and notochord (See Urochorda, Scroll of Animal Life).

Since the sea squirt possesses the chordate characteristics only in the larval stage, and, since the adult acorn-tongue worm possesses these characteristics only in part, they are both classed below the amphioxus (Cephalochorda). As the illustration (Fig. 50) shows, the amphioxus, a fish-like animal which lives almost imbedded in the sand at the sea-bottom, possesses all the above characteristics in the adult stage. Investigation has revealed the fact that the amphioxus is unquestionably a direct ancestor of the vertebrates. If the relationships of the acorn-tongue worm and the sea-squirt can be definitely ascertained, the lineal descent of the vertebrates will be fairly well established. This is especially true since the habits and struc-

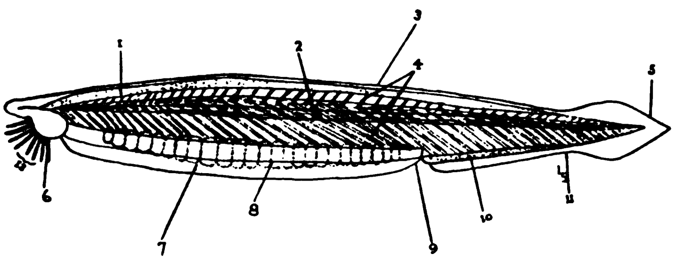


FIG. 50. Amphioxus. Unquestionably one of the ancestors of the vertebrates. 1. Nerve cord. 2. Notochord. 3. Dorsal fin. 4. Myotomes. 5. Caudal fin. 6. Oral hood. 7. Metapleural fold. 8. Gonads. 9. Atriopore. 10. Ventral fin rays. 11. Ventral fin. 12. Oral cirri.

ture of the larvæ show a close relationship with that of the starfishes. Thus, the remote ancestry of the vertebrates, including man, may be found back among the invertebrate animals.

The Lower Vertebrates

The Fishes.—All the animals listed on the chart (See Scroll of Animal Life) before *chordata* are characterized by the fact that any skeleton or hard parts which they may possess are always on the outside of the body (exoskeleton). The following are some typical examples of animals having an exoskeleton: corals, starfishes, mussels, oysters, snails, crayfishes, lobsters, and beetles. On the other hand, it is a well-known fact that the skeletons of the higher animals are found in the interior of the body (endoskeleton). A glance at a skeleton of the dog reminds us that those bones were once covered with layers of flesh, in contrast with the clam shell (Fig. 46) which once surrounded the animal. We may, therefore, conclude that in general (tho there are many exceptions) the higher animals possess a bony endoskeleton and the lower ones an exoskeleton. Then animals like the fishes, alligators, and turtles should be considered intermediate forms since they have an internal skeleton of bones and an external skeleton in the form of a hard covering of scales, or plates, much like the lower forms of life.

Still lower than these intermediate double-skeleton forms,

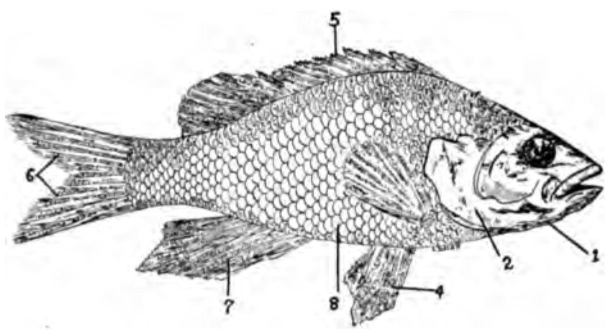


Fig. 51. Perch. 1. Pre-operculum. 2. Operculum. 4. Pelvic fin. 5. Dorsal fin. 6. Caudal fin. 7. Anal fin. 8. Ctenoid scales.

yet above the amphioxus, are certain fish-like animals which have a skeleton of cartilage. This would be expected, since the notochord of the amphioxus is composed of a gelatinous, almost cartilaginous material. The most lowly of these vertebrates are the hagfishes and the lamprey eels (See Scroll of Animal Life). These are principally sea-forms—their food being blood, flesh, and even the vitals of fishes to which they attach themselves with their rasping mouths. Although the cartilaginous skeleton is indicative of a very primitive form of life, the hags and lampreys possess other structures, such as nervous, circulatory, and respiratory systems which are more highly developed.

The dogfish sharks show an advanced step over the forms considered above. The latter have no functional jaws or lateral fins; the former have fairly well developed skeletons (tho yet cartilaginous), distinct gill arches, lower jaws, and paired fins. The hags and lampreys have soft slimy skins, while the dogfish sharks are covered with placoid scales—a type found only on primitive fishes. From these primitive fishes, we could follow, if space permitted, the line of development thru the common bony fishes (Teleosts, Fig. 51), with a well developed "fish" skeleton and a high type of scales (Ctenoid) to the animals like the frogs having typical bony skeletons and no hard outer covering—vertebrates in the truest sense of the word.

Amphibians (*Gr. amphibios, capable of living in both air and water*).—When viewed from an elementary standpoint, the life history of the frog, as heretofore presented (See Chapter VI and Fig. 32), tells the story of his place in the scale of life. The fact that it sacrifices its long tail for functional legs with feet, exchanges gills for lungs, and leaves the water, clearly ranks the frog considerably above the fishes. It is quite significant, however, to note that the common frog is the highest type of amphibian—the salamander being in a lower class. Some species of salamanders retain the true amphibian characters throughout adult life. That is, instead of the gills becoming non-functional and disappearing, they are retained; thus giving the animal the power to live for some time either in water or air. In other words, the adults of such forms correspond to a very young frog which still retains "tadpole" characteristics; namely, tail, gills, etc. As a suggestion of the relationships which exist between such low "amphibious" salamanders and the highly developed frogs, it should be noted that there are adult intergrades between these two extremes. For example, the legs of various salamanders are developed in proportion to their stage of phylogenetic progress. Even in the higher forms, the legs are insufficiently strong to carry the body entirely free from the ground without frequent rests. In the case of most salamanders, the body is pushed along the surface by the weak legs.

Amniota

The method of development of the eggs of reptiles, birds, and mammals is strikingly different from that of the amphibians and lower forms. It has been noted that the entire frog egg is converted directly into the body of the tadpole. The eggs of the remaining three classes—reptiles, birds, and mammals—develop in a strikingly different manner. In these forms, a peculiar double hood-like covering develops from certain parts of the egg, and, after completing certain characteristic stages of growth, completely surrounds and thus protects the developing embryo. This covering, which is considered somewhat more in detail in Chapter XXVIII is called the amnion. Its importance is evinced from the fact that all the animals of the three higher classes (reptiles, birds, mammals) are called *Amniota*. In this connection, it will be noted that the amnion, and other embryonic structures, are cast off at birth—having completed the functions for which they were formed.

Reptiles and Birds.—The developmental history, alone, shows that the reptiles and birds are worthy of a higher place in the tree of animal life than the amphibians. They not only possess an amnion, but at no time after the egg is hatched do they make the water their home or breathe with gills as do the larvæ of the amphibians. The recapitulation law, stating that each individual lives over the life of the race, is well illustrated in this connection. Although the reptiles do not live an aquatic life after the egg is hatched, their life during the embryonic stage is clearly an aquatic one since they are surrounded by the amnion and float in the amniotic liquid. This statement not only applies to the developmental life of the reptiles but is more or less true of the birds and mammals. However, a number of factors indicate that the reptiles should be ranked below the birds and mammals. Perhaps the most obvious of these, especially to the non-technical reader, is the fact that, although not truly aquatic, most of the reptiles accept a semi-aquatic life—spending a part of their time either in the water (alligators, turtles, etc.) or in damp places (most snakes). It is quite significant that, *as a general rule*, the less a class of animals uses a water environment as a habitat the higher they may be classed in the scale of life. Thereupon, the relative position of the fishes, amphibians, reptiles, and birds is shown by the fact that the fishes spend all their life in the water; the amphibians live in the water during their larval life and must have a damp environment during their adult life; the reptiles—although not truly aquatic—live a kind of semi-aquatic life; while the birds are, as a rule, entirely independent of water as a habitat, except, of course, while in the embryonic condition.

Mammals.—The dominant characteristic of mammals is the method of nourishing the young with milk from the mammary glands of the mother—hence the name *mammal*. Associated with this is the habit of bearing the young alive, the egg being fertilized and undergoing development in the body of the female. The relationship between this, the highest group of animals, and the class below—the egg-layers—is shown by the method of reproduction of the lowest mammals—the monotremes. These primitive forms possess mammalian characteristics in general but still lay eggs as do the birds.

As we ascend the scale of mammalian life (See Scroll of Life), a gradual increase is noted in the degree of perfection of the nervous system, especially in the brain and sense organ connections. Although most animals are undoubtedly governed by instinct, some of the nearer relatives of man exhibit considerable intelligence. "They possess the faculty of memory; they form ideas and draw conclusions; they exhibit anger, hatred, and self-sacrificing devotion for their companions and offspring that is different from that in man only in degree and not in kind" (Jordan and Heath).

Primates.—As Metcalf says: "Naturally the subject of the relation of humankind to evolution is one of particular interest to us. Study of human anatomy shows mankind to be probably a single species, belonging to the *Primates*, a group of the *Mammalia*, including, besides man, the lemurs, and the apes and monkeys of the eastern and western hemispheres. Man is most nearly related to the *Simiidæ*, the tailless apes of Asia and Africa, including the gibbon, the orang (Fig. 52), the chimpanzee, and the gorilla (Fig. 53). It is usual to place humankind in a distinct family of *Primates*, *Hominidæ*. . . .

Fig. 52 (left). Baby orang-utan.
Fig. 53 (right). Gorilla. (From "Animal Life," by Jordan, Kellog, & Heath, by courtesy of D. Appleton & Co.)

As an illustration of some of the reasons for asserting that men are primates and are closely related to the *Simiidæ*, glance at the illustration of the skeletons of representatives of four genera of *Simiidæ* and of man. Part for part the skeletons are the same in all fundamental regards. . . . But let us turn to structures other than the skeleton. . . . We think of the hairiness of the apes as distinguishing them rather sharply from man, but in reality the whole of the human body is covered with hair, save the palms of the hands, the soles of the feet, and the backs of the terminal joints of the fingers and toes; and these same portions are naked in the apes. Not only does hair clothe the whole human body, the slant of the hair in the several regions of the body is the same that we observe in the apes. Therefore, even to minute details, the apes and man can be compared as to the presence and slope of hair; the only considerable difference in the condition of the hair in the two being in the length and the coarseness of the individual hairs" (Fig. 54).

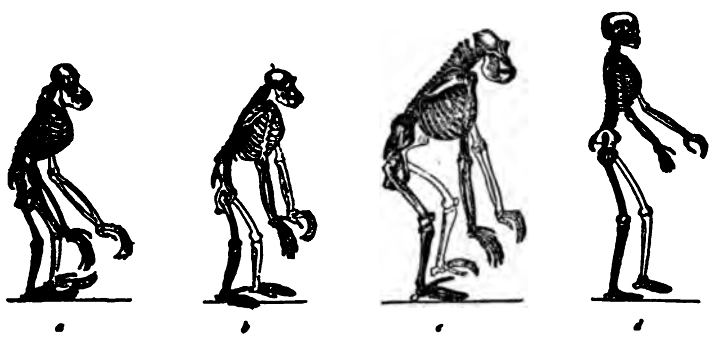


FIG. 54. Man and the higher apes. The complete skeleton of man is quite comparable to that of the other primates. a. Orang-utan. b. Chimpanzee. c. Gorilla. d. Man. (From Cockerell, after Huxley.)

Conclusion—Ancestral Tree (*Fig. 55*).—A very brief and superficial discussion has been given in which the principal groups of the animal kingdom have been taken into consideration. No discussion, in the space of as few pages, could possibly give more than *very elementary* facts. However, the reader should gain some knowledge of the advancing complexity of the animal kingdom. He should also form a conception of the relationships which exist between all animal life. The Scroll of Life, presented in Chapter VIII, will give more of the details should they be desired.

In conclusion, the ancestral tree, graphically showing the relationships of animals, is presented (Fig. 55). With the help of the Scroll of Life and the Chart of the Ages (Chapter IV), the reader should be able to form intelligent conclusions regarding the evolution of animal forms.

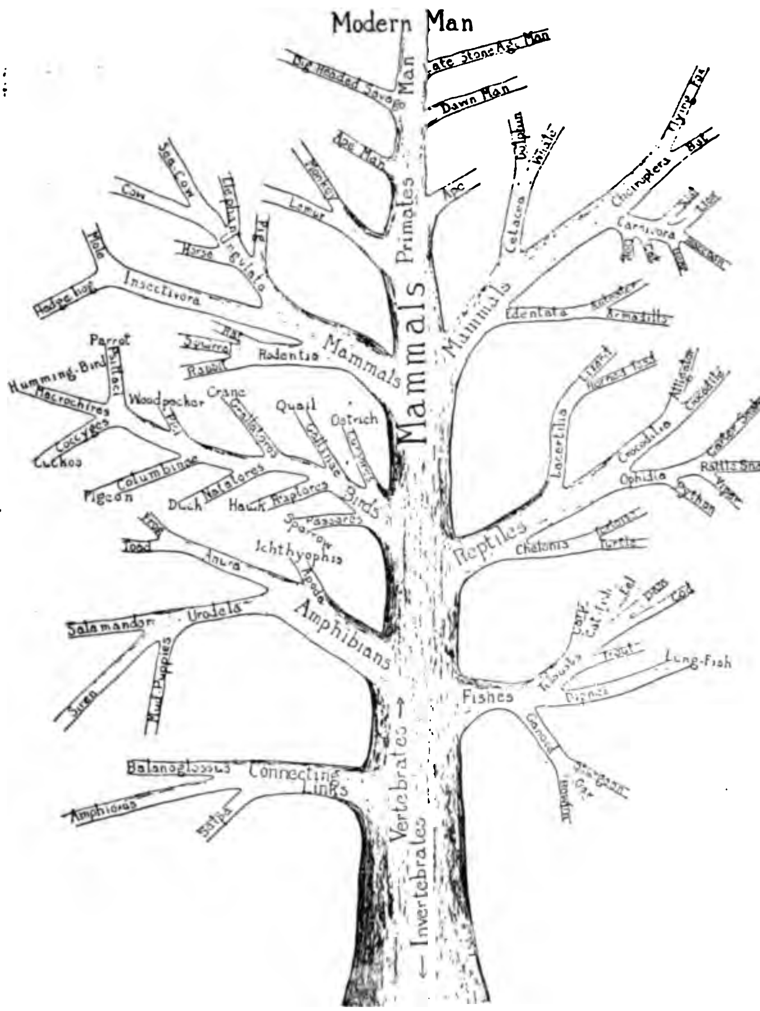


FIG. 55. The Ancestral Tree. A graphic representation of animal relationships in general.

CHAPTER X

ENVIRONMENT

Introduction—Factors of Environment—The Results of a Change of Environment—Temporary Changes—Changes of Longer Duration—Animal and Plant Distribution in Relation to Environment—Struggle for Existence—Poetic View—Scientific View.

"Environment is what the individual has, *for example: housing, food, friends and enemies, surrounding aids which may help him and obstacles which he must overcome. It is the particular world into which he comes, the measure of opportunity given to his particular heritage."*

—*Herbert E. Walter.*

The comparative value of heredity and environment has been a subject of dispute for many years. Galton expressed those two factors which control the destinies of both the individual and the race as "Nature" and "Nurture." The former refers to those characteristics which have been handed down from earlier generations through the parents, while the latter includes the sum total of the surroundings; the former is fixed and is beyond the power of any individual to change during his own life, the latter may be altered at any time; the former *locks* man securely to Nature, the latter *links* him temporarily with the elements and forces of Nature; the former is *Heredity*, the latter is *ENVIRONMENT*.

Altering the Factors of Environment

Such things as air, water, food, light, temperature, electricity, plants, animals, and the soil are factors that are present in nearly all the many types of environments—some are present in all environments, others are sometimes lacking.

The difference which marks one environmental condition from another is determined by the amount of variation of the several factors to which the individual is subjected. A change of environment, then, is simply an alteration of the degree or condition of the factors that determine it. This may be accomplished by the individual's changing to new conditions in a new locality, or by changing the factors themselves. For example, if one lives in the north and desires a warmer climate, he may either go farther south or build a fire to heat his room. To this extent every practical-thinking individual may become

FIG. 56. A certain species of grouse, probably, *Lagopus albus* spoken of in some localities as the "mountain quail," exchange the usual summer plumage for a glossy white winter coat. The snow-shoe rabbit and other mountain forms undergo corresponding seasonal changes.

the master of his own environment. Herein it lies that man is on a higher plane than the rest of the animal world.

Nature has provided certain simple methods by which most plants and animals can adapt themselves to changed environment (Fig. 56). Upon the approach of winter, those which cannot migrate either hibernate or neutralize the change by certain artificial means, such as living in dens, undergoing certain physiological changes, or changing the covering of their bodies. In winter, the amount of hair or fur on most mammals usually changes both in degree and advantageous arrangement. We sometimes lament the fact that the horse is not so sleek and beautiful in winter as he is in summer. However, the shaggy and loose hair is a very poor conductor of heat. Thus Nature has planned this simple method of keeping the animal warm. Furthermore, the natural changes of the skin of our

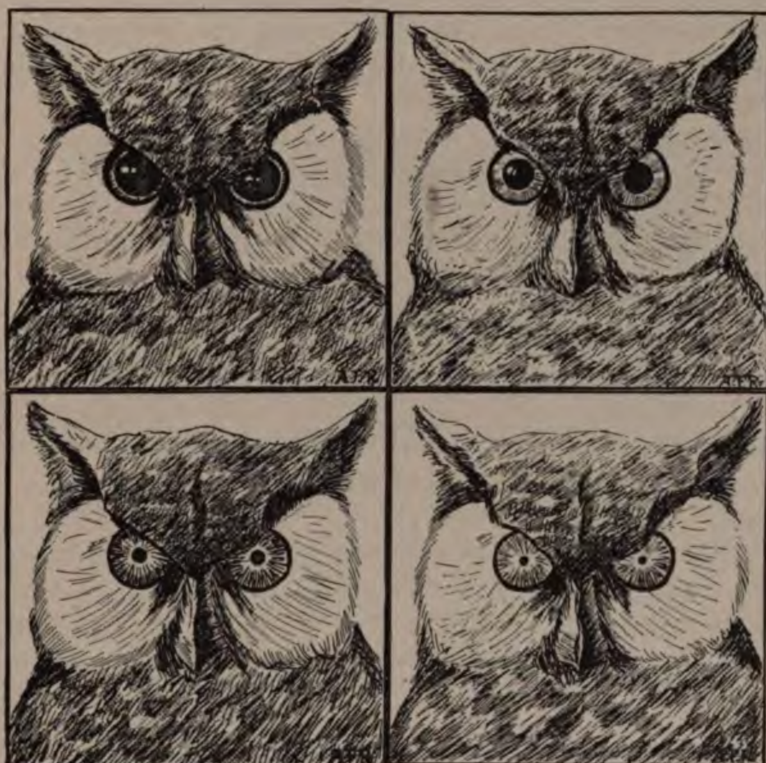


FIG. 57. The eyes of the western horned owl illustrate an adjustment to new environmental conditions. Although the entire body possesses mechanical and physiological power of adjustment, the eyes are especially sensitive. (Sketch from life under different light intensities.)

own bodies may be observed. Contrast, if you will, the loose and expanded feeling of the skin on some hot day with the "tight," shivering sensation felt during very cold weather. This is one example of the many natural responses that our bodies make to a change in their surroundings (Fig. 57).

Changes of Longer Duration.—It is generally conceded that such temporary changes as those considered above do not, as a rule, render a lasting influence upon the plants and animals which are subject to them. Such plants and animals will return to their former state when the normal environmental conditions are restored. However, if the change in any of the factors of the environment is of unusual duration, the corresponding change in the plant or animal structure may become more or less fixed. In passing from the plains to an altitude of nine or ten thousand feet, most people experience a certain discomfort due to the fact that the physiological internal pressure of the body is greater than the external atmospheric pressure. The ears may "ring," the eyes may turn red, the nose may bleed, or the person may experience a "heaviness" in the chest accompanied by shortness of breath or palpitation of the heart. These symptoms disappear after a few days and, except in rare cases, are totally overcome. However, the lack of physical endurance is quite noticeable for some considerable time. After a few months have elapsed, the individual seems to return to normal condition and the high altitude has no further perceptible effect upon the body.

Is it not obvious that some readjustment was made in the structure of the body and that this change was lasting so long as the environment remained unaltered? Would it seem logical to conclude that should children be born and live at such a high altitude, a sturdy race of mountaineers would result from this readjustment; and, further, that this "sturdiness" and ability to live at such high altitudes would be transmitted from one generation to another? Such was the process of reasoning of the scientists of the Nineteenth Century. The pros and cons of this old, and still perplexing question will be considered in future chapters (See Chapter XXIX).

Animal and Plant Distribution in Relation to Environment

The power to respond to environmental changes determines largely whether an animal or a plant can live in certain localities. If, in the above illustration, the individual continued being uncomfortable at a high altitude, with now and then an attack of "altitude fever," as is sometimes the case, he could not remain in that locality. Similar illustrations might be drawn from plant and animal life in general. If a large number of animals or plants were to be removed from their native haunts and taken to a colder climate, or vice-versa, some would die immediately. Others would live for a

FIG. 58. Potatoes raised by the author under the same environmental conditions. "Both had the same parentage, but one lot was propagated from the largest tubers in the hill, and the other from the smallest. Similar tubers are shown at the base of each bucket. Both lots were given the same treatment. The yield shown in the buckets was 25 and 27 pounds, respectively, showing no superiority in the product of the large tubers. Potatoes are reproduced vegetatively from the tubers without change in hereditary qualities, except in the rare case of bud and sport mutation. The experiment illustrates the non-inheritance of acquired characteristics. The little tubers are little because of differences in the time of development or position, broadly speaking of nutrition, and not because they have inherited different qualities. There are, however, other forms of the potato genus which have invariably small tubers, and these will produce nothing larger, being controlled by heredity." (From Cockerell's "Zoology." Copyright by World Book Company, Yonkers-on-Hudson, New York.)

while and perhaps produce a few offspring; but, owing to their limited power of adaptation, they would finally perish. Still others would adapt themselves to the new conditions and would remain to inhabit the new locality. Such are the experiences of plants and animals, including man, in every place. The principal task is for the living to adjust themselves to the changes in their environment. The *Laws of Life*, therefore, become the law of the *survival of the fittest*. It is recognized that the environment, and especially the power of adjustment to environment, determines the kind and character of living things in any locality (Fig. 58). One would not expect to find prairie sage brush in a tropical forest; nor would it be reasonable to expect banana trees to grow in the temperate zones. If an oak is found at high altitudes, it will invariably be the "scrub-oak," and not the large oak which is characteristic of the central states.

FIG. 59. Peaceful nature. Many beauties of nature would vanish could man see the struggles which are going on at his feet.

Struggle for Existence

In the foregoing pages, examples have been cited in which the plant or animal was forced to undergo certain hardships and perhaps even physical suffering before the necessary readjustment to the new conditions could be made. After a certain more or less prolonged struggle, the necessary adaptation in the cases of the most sturdy was brought about and the plant or animal was enabled to live in its new environment.

This same struggle, between the various forms of life and the elements of Nature, is being waged all around us continually. Nevertheless, as we cross a beautiful meadow on a quiet summer afternoon, we receive the impression that Nature is doing her work in a calm, serene, and peaceful manner. The daisies show no signs of the great battles which they have fought; the butterflies flit here and there as tho they were free from all cares; the lambs gambol playfully; the grass, the weeds, and the bees, in turn, fail to speak of their woes (Fig. 59).

"Is this a time to be cloudy and sad,
  When our Mother Nature laughs around;
When even the deep blue heavens look glad,
  And gladness breathes from the blossoming ground?

"There are notes of joy from the hang-bird and wren,
  And the gossip of swallows thru all the sky;
The ground squirrel gayly chirps by his den,
  And the wilding bee hums merrily by.

"There's a dance of leaves in that aspen bower,
  There's a titter of winds in that beechen tree,
There's a smile on the fruit, and a smile on the flower,
  And a laugh from the brook that runs to the sea."

When we turn from this superficial and poetic view and study the facts in detail, we find that Nature is not so calm, orderly, peaceful, and happy; but that in reality there is a constant *struggle for existence.* Before a meadow is planted all the weeds possible are destroyed. Many, however, remain, and from the very beginning dispute the right of the clover. Since the latter outnumber the weeds the battle is won, for a few years at least. Soon the clover, after being constantly preyed upon, and being under certain other disadvantages, loses the fight and the field is entirely taken by weeds. In this case, the struggle would seem to be over, but such is not the case. Other wild plants are on the ground by this time to dispute the right of those victorious over the clover. Thus, the battle rages in the meadow, on the hillside, and in the dale. While studying such a problem as this, Darwin co^nn^

twenty species of plants on a plot of ground whose area was about a square yard. A few weeks later, after some of the plants were grown, he found that the struggle for space had been so keen that nine species had entirely disappeared.

This incessant combat of the plants is carried on not only among themselves but with the animals as well. As soon as the seeds are formed, the birds begin to feed upon them. After the seedlings have "struggled" with the soil for moisture, hundreds of insect larvæ are ready to feed upon the tender rootlets. As soon as the little plant shows its head above the ground, the birds, and certain insects, begin to pick and nibble at its white leaves. If it evades these enemies and grows to a height of four or five inches, it becomes the food of caterpillars and various herbivorous mammals such as the horse, the cow, and the rabbit. Or, perchance, the otherwise successful plant may be uprooted by such animals as the hog, the muskrat, or the mole.

The struggle for existence in the animal world is equally as strong as in the plant world. Animals fight not only among themselves and prey upon each other, but they must also combat the elements of Nature. In certain mountain districts of Colorado, the author has been interested in recording the struggles of the common rabbit. Since the rabbit is a vegetarian it is forced to live in or near some grassy mountain ravine. There it has plenty of food and shelter, and it would seem that its life would be very easy. From a similar study of the other forms of animal life, a decidedly different opinion was reached, for such grassy plots are the hunting grounds of coyotes, weasels, skunks, hawks, owls, and men—all searching for the rabbit, with the intent to kill it and devour its tender flesh.

This struggle of the rabbit was especially apparent in one particular ravine that has come to the notice of the author. It was such a plot as considered above, until, in the late summer, the herdsmen drove a flock of some two thousand sheep into the little valley for grazing. Within two days the ground was as barren as if a devastating army of Huns had passed, except for here and there a solitary yucca plant. The rabbits, no longer having food and shelter, were forced to migrate to the neighboring foothills. There the struggle for food was unendurable, and the escape from their enemies almost impossible on account of the scanty vegetation. In turn, the other animals, including man, no longer had any occasion to visit the once popular hunting ground. The plant life of the place underwent a change; for, when the following spring came, more sturdy and hitherto less abundant plants had an equal chance with the descendants of those eaten by the sheep. Thus, under such conditions, it would happen that both plant and animal life would be entirely recast in a very brief space of time. Wallace reminds us that: "The introduction of goats into the island of St. Helena led to the entire destruction of the native forests, consisting of about a hundred distinct species of trees and shrubs, the young plants being devoured by the goats as fast as they grew up."

In the case of the birds, the struggle continues from the time the eggs are produced until the death of the individual. In some cases the eggs are not fertilized; at other times they are eaten by other animals. It is a well known fact that young birds are the favorite food for certain birds, snakes, and other animals. If they escape these enemies, the climate may be too hot, too cold, too dry, or the food supply may be insufficient. In such cases the struggle ends in failure—the birds perish. It is evident that those which escape their enemies through their early and adult life and produce offspring are rare exceptions.

From the above discussion, the reader should reach the conclusion that the "struggle for existence" does not necessarily mean an actual struggle, in the sense of a physical combat of individual with individual, but rather a struggle to obtain food, shelter, light, air, and, in general, a chance to live—a battle with the factors of environment.

CHAPTER XI

THE PRODIGALITY OF NATURE

Rapidity of Multiplication of Plants and Animals—Ferns—Dandelions—Bacteria—Flies and Other Insects—Elephants—Horses—Man—Elimination of the Unfit Variation—The Effect of the Elimination of the Unfit upon the Race.

"Earth, that nourished thee, shall claim
Thy growth, to be resolved to earth again,
And, lost each human trace surrendering up
Thine individual being, shalt thou go
To mix forever with the elements,
To be a brother to the insensible rock
And to the sluggish clod, which the rude swain
Turns with his share, and treads upon."
—*William Cullen Bryant.*

When we consider the fact that all living things are engaged in a lifelong and incessant struggle among themselves, with their enemies, as well as with the various forces of Nature (Fig. 60), it does not seem possible for life to continue multiplying with the usual tremendous rapidity. However, in most species the death rate is balanced by the number of new individuals that survive; usually the death rate is exceeded many times over by the birth rate. In this manner Nature is enabled to keep the earth populated with the many species of plants and animals which inhabit it.

Examples of the remarkable rate of reproduction of plants and animals may be found all about us. Let us consider a few of the most familiar of these instances of prodigality. It has been estimated that a common fern plant produces over fifty millions of spores, each of which is capable of producing a new plant. At this rate, if every new plant could live and produce spores in the same way, the offspring of a single fern plant would cover eighty millions of square miles within a space of only two years. Such a state of affairs, of course, is impossible, for the many factors of environment are constantly at work to prevent anything more than a normal distribution and production of such plants. The variations in the condition

Fig. 60. Elks struggling with so-called "civilized" man's brutal instinct to kill.

of the soil, and the differences in temperature and moisture act as a check upon such abnormal conditions.

When we inquire into the phenomenon of the reproduction of the common dandelion, we can easily account for the rapidity with which it spreads. The dandelion is a hardy plant, capable of crowding others for room in which to grow. Very often lawns are seen in which the grass is almost, if not entirely, displaced by dandelions. However, this factor of sturdiness is not the only one that is responsible for such a wide dissemination. One healthy dandelion plant will produce about sixty seed stalks each year, and each stalk will bear approximately two hundred winged seeds. Should each of these seeds mature into a similar plant, and should each of these plants produce productive seeds, the offspring, removed the fourth generation from the original plant, would (allowing one square foot to each) cover a land area of a little over 245 times the size of the United States (Continental). The following tabulations will show graphically how this astounding result was obtained:

Area of the United States (Continental)	3,026,789 sq. mi.
1 sq. mi. contains	27,878,400 sq. ft.
The United States contains	84,382,034,457,600 sq. ft.
One dandelion will produce in the	
First generation	12,000 plants
Second generation	144,000,000 plants
Third generation	1,728,000,000,000 plants
Fourth generation	20,736,000,000,000,000 plants

20,736,000,000,000,000 ÷ 84,382,034,457,600 = 245 plus.

It is commonly observed that milk will sour within a very few hours, that bread will rise in thirty minutes, and that meat will become putrid overnight. Such sudden changes are due to the remarkable rate at which bacteria multiply. Metcalf has said: "Under favorable conditions a single bacterium might produce a million bacteria in a day. If this rate of increase should continue, we would have at the end of a week a million million million million million million million bacteria, all derived from the single individual with which we started." Bacteria are the most prolific of all living creatures. As they are so exceedingly small, the struggle for space is not so keen with them.

The rapidity with which flies multiply is also amazing. Each female fly lays on an average of one hundred and twenty eggs. It takes these eggs from fifteen to twenty days to mature into adult flies which are capable of starting new generations. If one should start with one wintered-over fly in the middle of April and run to the tenth of September—disregarding the death rate, and counting all eggs as maturing—there would be over five trillion flies. These flies, placed end to end at the equator would circle 880 times around the earth. The great naturalist, Linnæus, has been given the credit for the startling statement that three common flies could devour a dead horse in less time than could a lion. He based his conclusions on the assumption that each fly would produce 20,000 larvæ.

Charles Darwin has said: "The elephant is reckoned the slowest breeder of all animals. It begins breeding when thirty years old and goes on breeding until ninety years old, bringing forth six young in the interval and surviving to be a hundred years old. If this be so, after about 800 years there would be 19,000,000 elephants alive descended from the first pair." It would not take many more centuries to literally cover the earth with elephants if all adverse conditions could be brushed aside. "Even slow-breeding man," says Darwin, "has doubled in twenty-five years. At this rate in less than a thousand years there literally would be no standing room for his progeny." Although man lives largely under artificial conditions, the *Laws of Life*, in many respects, apply to him as well as to the lower animals. Although the death rate with man is usually considered sufficiently high to prevent any serious overcrowding, we must admit that the population does double in certain localities very often and that the problem is becoming a very serious one (See Chapter XXX).

Although the above illustrations give us some conception of how an incessant struggle is possible without the entire elimination of the species, the suggestions offered are more or less absurd; and the height of absurdity is reached when we assume, as we have, that an animal or a plant could live in perfect harmony with its environment, thus presenting a negligible death rate. If it were possible to eliminate all competition, save that within the species, warfare would continue between individuals. At a certain proximity, each animal would dispute the right of food and territory with the members of

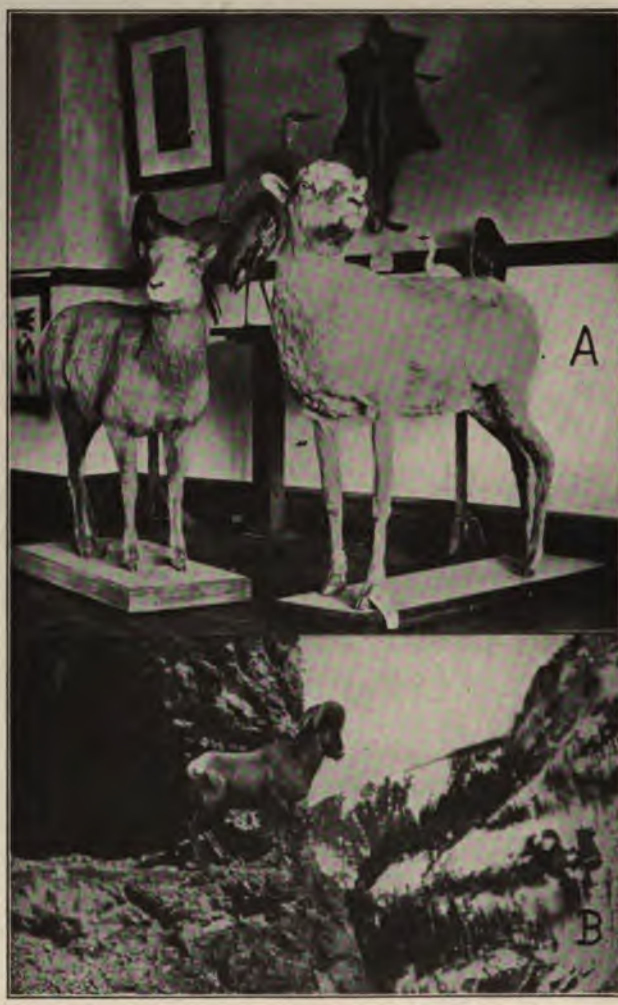


Fig. 61. Mountain sheep. Note his humble and subdued position in the halls of learning (A), into which he has fallen from his heights of dignity in God's Universe of Nature (B).

its own family. If we could assume it to be possible for them to escape death by starvation, cold, heat, drought, storm, enemies, and disease, we should still find many victims as the result of civil strife. We may conclude, therefore, that Nature is not calm, peaceful, and orderly, as would appear when we observe with such great admiration "the birds singing in the trees, the insects hovering over the flowers, the squirrel climbing among the tree-tops, and all living things in the possession of health, and vigor, and in the enjoyment of a sunny existence" (Wallace). On the other hand, it seems to be Nature's business to reproduce life a million-fold in order that each form may prey upon other forms. Life is difficult and disappointing, and of the millions of forms which are produced, those which succeed are the rare exceptions (Fig. 61).

Elimination of the Unfit

Variation.—Although the oft-quoted expression, "Like begets like," has come to be universally accepted, it is equally true that *like begets unlike.* A child may have eyes and hair like his mother, although he may be strikingly different from her in other respects. In fact, we are prone to note the resemblances and disregard the differences. We often speak of a child as resembling his parents when he really differs in all respects save one or two. A study of any group of brothers will reveal a set of markedly different characteristics. One may be tall, another short; one may have dark hair, another light; one may be dull and stupid, another quite intelligent; one may be quick, another sluggish; and, thus, we might continue to find many differences.

A brief comparison of the individuals of any one of the groups of lower animals will reveal the fact that many variations exist between them. Our attention is called to a team of horses which are said to be "perfect mates." A mere glance, however, discloses many dissimilarities. They may both have a "blazed face," but the marks will have different shapes; they may both have white feet, but one will probably have more white than the other.

Among the individuals of any of the wild species of animals, rabbits for example, some will be found that are at va with the rest. One individual may be more fleet th other, another may be more cunning, another may have more endurance, while another may be bolder than its fellows. The character and the degree of these variations determine the fate of the individual in its struggle for existence.

The Test of the Fit.—We have seen that the rate of reproduction of all living things is enormous, and that, as a consequence, the struggle for existence must be very acute. What, then, is the test of the fit? What are the factors that determine which individuals are to survive? The adult English sparrows present many striking differences. Some have broader breast markings than others; some are shy, some are bold; some are large, some are small; some become stronger and have greater endurance, some are weak; still others fly with greater swiftness than their fellows. David Starr Jordan has shown that, were no English sparrows to die except of old age, it would take only twenty years for them to multiply until there would be one sparrow to every square inch in the state of Indiana. In order to keep the sparrows from increasing—as Jordan's illustration goes—the death rate of these birds must be exceedingly great. The question arises, then, as to which of these birds will perish under the stress of the environment. If the food supply is not abundant, the bold, strong, and alert will force starvation upon the weak and shy; if pursued by an enemy those swift of wing and those with greater endurance will survive the weak; if the winter is unusually severe, only the strong and those with the greater resistance will be permitted to live. Whatever the test of Nature may be, those individuals least fitted for life in a given environment will perish, leaving the stronger and better fitted to be the progenitors of the next generation.

We have seen, therefore, that Nature produces a great many more plants and animals than could possibly live in a given community, and that she has caused them to be placed at great disadvantages and under strenuous competition. She has set up an actual warfare between them and their surroundings in order that the best, the strongest, and the most fit may be selected to become the parents of the next generations. Darwin and Wallace called this "Natural Selection" to distinguish it from the artificial selection of the best plants and animals by the breeder. Herbert Spencer should be credited for designating this phenomenon as the "survival of the fittest." "It will be readily seen, however, that the process in Nature is not so much a selection of the fittest, as a *rejection of the unfit;* the unfit are eliminated; while the fit survive." It has been suggested that "natural rejection" would be a better name than "natural selection." The whole process of Nature, therefore, seems to be devoted to one great task; namely,

The Elimination of the Unfit

Which Are the Unfit?—What specific interpretation should be placed upon the terms "fit" and "unfit"? If the unfit are to be eliminated, which individuals are to perish? The "unfit" *are those plants and animals which are inferior in the characteristics upon which safety depends.* With the lower animals, these qualities are usually those of physical ability—no moral obligations being involved. The mountain lion (*Felix hippolestes,* which is still quite common in the Rockies), a very ferocious wild beast, can quickly and unhesitatingly deal his deadly blow upon the unsuspecting mountain sheep, deer, or even larger prey. The one which can make the surest leap from the ledge above, landing upon his prey instead of a sharp rock below; the one with the least respect for innocent lives, will generally survive the struggle for existence—he is the *fit.* Altho not generally so considered, animal intelligence may be one of the qualities of the fit. Experience seems to have taught the mountain lion that man is very dangerous prey. Thus, we no longer hear such stories as were formerly told of the combats between man and lion. He has even learned not to molest animal life when man is near. If the lion is not true to the intelligence of his race, he may perish, though fit in many other respects.

An old miner of the Colorado Rockies tells a thrilling story of a mountain lion which leaped from a cliff down upon one of his pack burros which was plodding along a mountain trail. The large pack upon the back of the animal caused the lion to miss his mark and to go tumbling down the rocky hillside into the gulch below. Being stunned by the fall, the lion was unable to escape the sure fire of the sturdy old miner's gun. Thus, one of the largest, strongest, and most ferocious of the "kings of the mountains" was eliminated as intellectually unfit, because he was deficient in that one special quality upon which his safety depended. Wallace summarizes the qualifications of the "fit" thus: "At one period of life, or to escape one kind of danger, concealment may be necessary; at another time, to escape another danger, swiftness; at another, intellect or cunning; at another, the power to endure rain, cold, or hunger; and those which possess all these faculties in the fullest perfection would generally survive."

The Effect of the Elimination of the Unfit upon the Race.

In the illustrations considered above, attention was called particularly to the effect upon the individual of the various factors mentioned, no note being given to the effect upon the race. Let us consider again the case of the mountain lions. Suppose that it were the characteristic of *all* such lions either to prey upon man or disregard him and attack his domestic animals in his presence. If this had been the case these animals would have been eliminated from America long ago. Since this habit was a variation from the characteristics of the race, with only a few originally possessing it, man feared only the few. Since the advent of man into the Rockies, the lions which might have become the parents of a ferocious and dangerous race on account of their boldness have been killed off, generation after generation, until now such incidents as related by the miner are practically, if not entirely, unknown. Should all the individuals of any one particular family of ferocious lions not be killed during one generation, their offspring, possessing this characteristic, would be gradually eliminated. The exceptional animals with these habits, the *variants*, which would appear in other families, would perish in like manner. The way in which these exceptional forms arise will be considered in future chapters. Probably by the above considered process of elimination, a race of mountain lions which fears man has been developed.

In the case of rabbits which are subjected to extreme hardships, the results would be in the direction of an adaptation to the environment. Those with less endurance, the "unfit," would first fall prey to owls, weasels, and coyotes. Their number thus being decreased, these enemies would begin a more spirited search until those rabbits of average keenness and swiftness, together with many of the strongest, would fall victims. There would then be left only those which were by far the swiftest, the most alert, and those which could live longest under the most trying circumstances, such as extreme cold and starvation. These would be the ones which would propagate the race of rabbits in that particular locality. Thus, without considering at this time the method of the origin of the "fit," we may conclude that if this process should be continued for a number of years, there would remain only those best adapted to the new and strenuous environment—only the *fit*. "Thus Nature seized upon favorable variations and after a time, as the descendants of each of these individuals also tend to vary, a new species of plant and animal, fitted for the place it had to live in would be gradually evolved" (Hunter).

CHAPTER XII

VARIATION

Variation—Dissimilarity of Plants and Animals—Darwinism Based upon Dissimilarity—Neo-Darwinism—Beneficial and Harmful Variations—Positive and Negative Variations—Normal and Abnormal Variations—Continuous and Discontinuous Variations ("Sports")—Fluctuating ("Fluttering") Variations—Quételet's Law—Quételet's Curve.

"We command Nature only by obeying her laws."
—Lyell.

Dissimilarity in Nature.—Attention has been called to the fact that, although we tend to resemble our parents, we are usually quite different from them. Our hair may be a little lighter, or a little darker; we may be taller, or shorter; lighter, or heavier. The complexion is never just the same. Sometimes we are a little more excitable, or a little calmer than our parents. Dissimilarity is found throughout all nature. In fact, it has been said that nothing in Nature is constant except constant change. This same general fact is true in all the many species of living creatures. *Variation* is universal; it applies to plants and animals alike.

These dissimilarities which exist in the plant and the animal kingdoms have been noted for many centuries. During the Middle Ages, when writers were engaged in writing "descriptions" (Natural History), these external differences formed the bases for their work. A little later the general conditions which existed in Nature were studied to a certain extent, but no attempt was made to ascertain the factors which influence variation. Still later, however, these variations, together with inheritance, formed the basis for Darwin's theory of organic evolution. However, Darwin was ignorant of some of the most important facts of variation. This suggests that we no longer accept Darwinism as presented by Darwin, Wallace, and others. The term Neo-Darwinism has been applied to certain recent interpretations of these old principles. Although Darwin has undergone many revisions and additions, it is the original key which has unlocked many great secrets of Nature. This fact alone has made it possible for the Twentieth Century biologist to work out some of the Laws of Life.

Types of Variation.—It so happened that a large proportion of the students of variation, especially in Darwin's time, were botanists. However, after the field was once opened, many workers, zoölogists as well as botanists, became interested and began thoroughly to investigate the phenomena of the causes and results as applied to variation. Darwin was well aware of the fact that variations were not of equal importance. In some cases a variation of a certain type may be of *direct benefit* to the plant or animal possessing it, while other types of variation may be very *harmful.* The former may be illustrated by the case of the rabbits mentioned in Chapter X. A rabbit that tended to vary from its parents in that it possessed more speed on foot would be more likely to evade enemies. The possession of a variation in the form of a more protective coloration, such as a dull gray, would be a very useful one. On the other hand, a variation in the opposite direction would be not only harmful, but dangerous. If its color should vary so as to be extremely light, it would bear less resemblance to the vegetation and soil and, thus, would be more conspicuous to its enemies. We would conclude that a swift, gray rabbit is much more likely to live than a clumsy, white one. In all probability this, especially the coloration scheme, accounts for the comparative absence of white rabbits in the wild. Certain variations may be useful under some circumstances and harmful under others. The dark gray color of rabbits which is so protective during the larger part of the year becomes a very harmful variation in winter when the snow is on the ground. Fortunately, many animals are so adjusted that they change their color to meet new environmental conditions. Rabbits do this to a very great extent, the snowshoe changing almost completely. The grouse (Fig. 56) exchanges its dull feathers for those of a white color when the winter snows come to its habitat.[1] The thornless rose is more likely to be eaten by cattle and other herbivorous animals than are roses with thorns. From this viewpoint, then, thornlessness is a harmful variation. However, since the thornless rose is more convenient to handle than those with thorns, the thornlessness becomes a useful variation in that roses of this type would be more likely to be cultivated and protected by man. This artificial protection, in this particular case, is more far-reaching than the natural protection by thorns.

It will be noted that in the case of the thornless rose, one characteristic is entirely lacking; that is, something has been subtracted from the normal rose. This type of variation is spoken of as a *minus*, or *negative*, variation. Many other examples of negative variations might be cited, such as tailless cats and dogs, white (albino) rabbits and mice in which pigmentation is lacking, hornless cattle, and spineless cacti. In order to be a minus variation, the characteristic does not need to be *entirely* absent. A sheep with a tail only slightly shorter than the others, a man with small feet, or a cornstalk shorter than the average are all examples of negative, though perhaps slight, variations. The opposite kind, in which additions have been made to normal characteristics, are classed as *plus*, or *positive*, variations. Some of the extreme examples of this type are spine-covered holly leaves, Japanese cocks with tails eight to ten feet long, and giants of various kinds.

It has perhaps occurred to the reader that many examples of variation are quite common and are to be expected at any time, while many others are very exceptional and could be

[1] For recent considerations of the problems of protective coloration, see the works of Reighard, Thayer, Roosevelt, Longley, Sumner, Mast, Young and others.

expected to occur only at rare intervals. We are not surprised when we see a lady with feet smaller than the average, or with hair that is unusually red. Nor would we expect all the leaves of a tree to be exactly the same size. Such variations as these last are classed as *normal variations*. On the other hand,

Fig. 62. A living double-headed calf. (An abnormal variation.) This calf eats through either mouth. It has two normal eyes and a double non-functional middle eye. (From Goldsmith, *Journal of Heredity*, Vol. XII, May, 1921.)

such variations as in the case of a child with three legs, or six fingers on one hand, a calf with a double head (Fig. 62), etc., are actual occurrences, but fall far outside the realm of human expectations. They are, therefore, classed as *abnormal variations*. These unusual and sudden, or *discontinuous variations* were noted many times by Darwin, who spoke of them as "*sports*." Although he went so far as to suggest that these extreme variations might sometimes give rise to new forms, he considered them of subordinate importance as a factor in evolution. On the other hand, he contended that the slight or *continuous variations* were of paramount importance in the process of evolution. These variations which blend into each other without any perceptible steps (continuous variations) were so popular with the adherents of Darwin's principles that they came to be called *Darwinian variations*. It was these slight but ever-present variations that natural selection was supposed to call upon when making its choice of individuals in providing for the survival of the fittest. According to this early assumption, by selecting the fittest, generation after generation, these minor variations, by sliding along the scale in one certain direction, would culminate in a prominent change. A measurement of over three hundred cottonwood leaves, picked indiscriminately from the same tree, revealed the following facts regarding the variations in leaf length, and serves as an example of normal variation.

Length of leaves in inches	¾	1	1¼	1½	1¾	2	2¼	2½	2¾
Number of leaves (Frequencies, Fig. 63).	1	5	11	12	13	21	23	42	61

Length of leaves in inches	3	3¼	3½	3¾	4	4¼	4½	4¾
Number of leaves (Frequencies, Fig. 63).	57	27	18	10	8	6	3	1

The first line represents the length of the leaves in inches, and the second the number of leaves found to have each particular measurement. It is obvious that the length of the leaves varies around 2¾ inches as a standard. The same might be said of the width, the shape, and so on. A similar investigation will reveal the fact that the ever-present continuous variations of *any* form in nature will not vary in any one specific direction, but, rather, that they will vary around the average, or the mean. Under these conditions, the Darwinian variations are said to be fluctuating about a mean, and, thus, the term "*fluctuating variations*" has been added to the category.

While attempting to find a simple method of explaining fluctuating variations, the attention of the author was attracted to a sparrow which had entered his office thru a small space at the top of an open window, and was seeking a means of escape. The sparrow's fluttering actions were so varied as to suggest fluctuating variations in nature. In order to carry the illustration farther, one end of a coiled wire spring from a delicate balance was attached to one end of a stick and the other end of the spring was fastened to one of the sparrow's

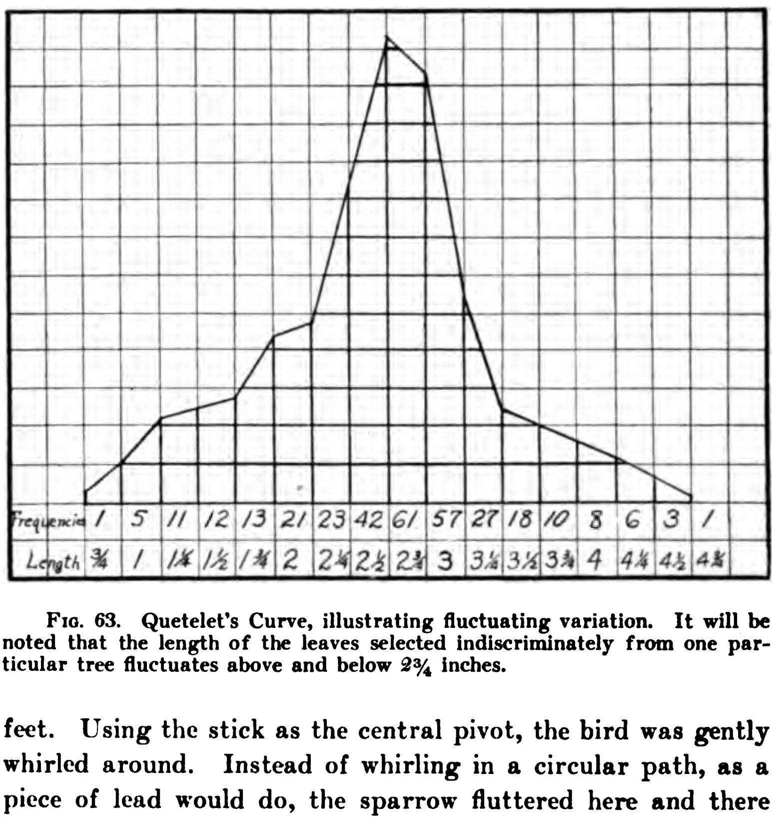


FIG. 63. Quetelet's Curve, illustrating fluctuating variation. It will be noted that the length of the leaves selected indiscriminately from one particular tree fluctuates above and below 2¾ inches.

feet. Using the stick as the central pivot, the bird was gently whirled around. Instead of whirling in a circular path, as a piece of lead would do, the sparrow fluttered here and there around the stick—the distance from the center being sometimes less, sometimes greater, but striking a general average. The actions of the sparrow clearly suggested the term "*fluttering*" variations. This is illustrated diagrammatically in Figure 64.

Quételet's Law.—If any characteristic of *any* individual be considered, it will be found to fluctuate around a mean, as shown in the accompanying diagram (Figure 64). In this and similar illustrations it will be noted that *the less variations from the average* (represented by the circle, A, Figure 64) *the greater number of occurrences; and the greater variations from this mean, the less they are found to occur.* In the words of Gager: "The more any given character departs from the

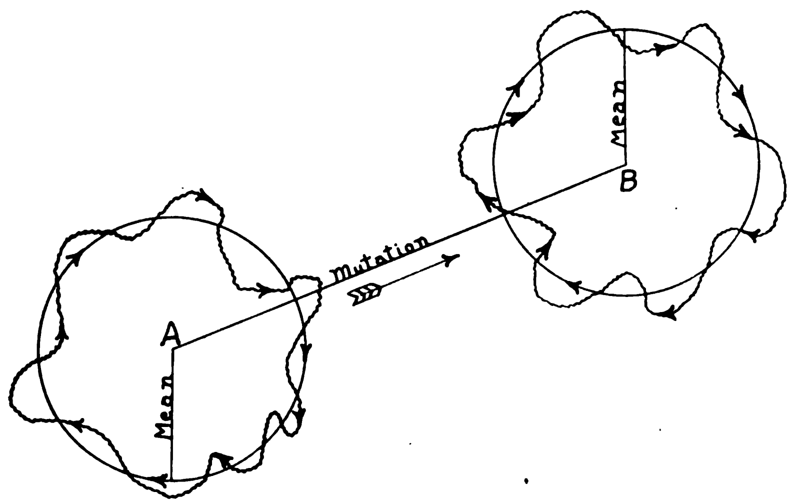


FIG. 64. Diagram illustrating the difference between the fluctuating variation and mutation. The two circles of which A and B are centers represent the average (mean) around which any character may fluctuate, indicated by the irregular lines. Any marked change from this average, as from A to B, is a mutation.

average of that character, the less frequent is its occurrence." This statement of the above considered facts is of sufficient general application to be called a *law*. Having first been suggested (1864) by a Belgian anthropologist named Quételet, (Pronounced Ket-lay), the generalization is spoken of as Quételet's Law.

CHAPTER XIII

MUTATION

Theory of Evolution Based upon Facts of Variation—Darwin's "Origin of Species"—De Vries and the Mutation Theory—Evening Primrose—Examples of Mutations—Polled Herefords—Disease-resisting Cabbage—Purple Beech—Oak-like Walnut—Shirley Poppies—Ancon Sheep—Davenport's Fowls—Strawberries—Roses—Clover—Sunflowers—Seedlessness—Taillessness—Progressive, Regressive, and Degressive Mutations—Causes of Variation—Somatic Variations—Outside Influences—The Cell as a Basis.

"The problem of the exact nature of factor mutations is only a phase of the general problem of the nature of living protoplasm, the solution of which is one of the ultimate aims of biology."
—Babcock and Clausen.

If, in the experiment with the sparrow (See last chapter), the stick which served as a pivot should be moved to some other position (B, Fig. 64), and the swinging continued, the action of the bird would be quite the same—except about a new center. This is suggestive of a discontinuous variation or a *mutation.* Since a well-known theory of evolution has been founded upon the observed facts of mutation, space should be given to a rather detailed consideration of this vital subject.

Altho mutations, *or the sudden appearance of a plant or animal with distinctly new characteristics which breeds true from the start and which fluctuates around its own new standard* (Fig. 64), were never observed as such until within the last few decades, cases of extreme variation had been noted even before Darwin's time. Since slight (fluctuating, continuous, or Darwinian) variations formed the basis for Darwin's theory of evolution, it would be natural to assume that he had the privilege of observing the more extreme types. As has been said before, he called these extremes "Sports" but failed to comprehend their real significance as evolutionary factors. From the standpoint of our present knowledge, it seems remarkably strange that a mind such as Darwin's could not see the evolutionary value of such extreme types of plants and animals. However, it must be remembered that the situation was entirely different then. The theory of the spontaneous origin of life was still uppermost in the minds of men, and Darwin was laboring to overthrow this erroneous belief. Indeed, if it had been announced at that time that new plants and animals actually appeared suddenly (out of the sky, as it were), the supporters of this theory of special creation would have claimed them as exemplifications of their doctrine. Thus, Darwin's theory of evolution might have fallen by the weight of its own revelations. From this standpoint, then, it seems quite fortunate that Darwin was blind to the significance of these new forms. However, he did suggest that they might *occasionally* breed true.

Darwin's announcement (*Origin of Species* 1859) to the effect that slight variations acted upon by natural selection were responsible for the formation of new species, drew out a great storm of criticism, and, thus, acted as a stimulus for the the most intensive kind of investigation. Almost immediately after the announcement of this theory, a great German zoölogist named Von Kölliker (1817-1905) suggested, in opposition to Darwin's theory, that species arose suddenly by mutation ("saltation"). This new field was further exploited by Korschinsky, a Russian. It remained for Hugo de Vries, a Dutch botanist, to establish the *Mutation Theory* upon a sound experimental basis.

De Vries and the Mutation Theory of Evolution.—Hugo de Vries, director of the Botanical Garden in Amsterdam, experimented with a number of plants, but his principal proof of discontinuity in variation (mutation) is based upon a twenty years' study of the evening primrose (*Œnothera la-*

marckiana, Fig. 65). This plant, which is cultivated in many of the parks in Europe for its showy yellow flowers, was supposed to have been imported from America—probably from Texas. De Vries' first observations seem to have been made upon plants

Fig. 65. The evening primrose (*Œnothera Lamarckiana*, left, and O. gigas, right), which served as the experimental basis for the mutation theory. (From Babcock & Clausen, after de Vries.)

of this species which had escaped from cultivation and were growing wild in an abandoned potato field at Hilversum in Holland. The evening primrose is a biennial plant which bears its flowers at the ends of its branches. In clear weather, the flowers open in the evening and remain open until the following morning. They may remain open much longer when the weather is cloudy. The flowers are pollinated by bees and other insects.

While studying Lamarck's primrose, which was growing in this most notable potato field, De Vries noticed two other species of the plant, which seemed to have appeared suddenly. Since they were new forms, making it impossible for them to have been introduced from other cultures, it was quite evident that they had arisen as derivatives from the *Œnothera lamarckiana*. As this behavior suggested great possibilities in the plant, type species were removed to the Botanical Gardens of Amsterdam for more intensive study.

Œnothera Lamarckiana and Its Mutants

Generation		Gigas	Albida	Oblonga	Rubrinervis	Lamarckiana	Nanella	Lata	Scintillans
No.	Year								
VIII	1899		5	1	0	1,700	21	1	
VII	1898			9	0	3,000	11		
VI	1897		11	29	3	1,800	9	5	1
V	1896		25	135	20	8,000	49	142	6
IV	1895	1	15	176	8	14,000	60	73	1
III	1890-91				1	10,000	3	3	
II	1888-89					15,000	5	5	
I	1886-87					9			

The above table shows that a number of new types were derived from the original plant during the indicated years of observation. At the top of the table may be noted the names of the mutations which appeared during the process of experimentation—1886 to 1899. The numbers in the columns under each name represent the number of mutations of that particular "species" during the year indicated. A careful study of this table will show the following facts regarding the mutations of the evening primrose; and, in addition, mutations in general:

1. Each species has its characteristic mutants. In the case under consideration, at least one mutant (*O. nanella*) appeared every year. Others were quite common and appeared in relatively large numbers. This rule has later been found to be

FIG. 66 (left). An achondroplastic dwarf (22 years old), showing stubby fingers which are oftentimes confused with brachydactylism (absence of joints). Whether the man is a "sport" or a "mutant" can be determined only by his offspring, as his parents are normal. (Right.) The accompanying photograph shows the size of the dwarf in comparison with an eight-year-old boy.

one of more or less general application. In the human race, for example, brachydactylism (short and stumpy fingers) is of common occurrence (Figs. 66 and 67).

2. A species may "throw" a very rare type of mutant. The chart shows that in 1895, and at no other time, the mutant *O. gigas* appeared. In truth, the examples of mutations which follow this summary will show that it is this exceptional type

of mutant which is the basic factor of plant and animal development.

3. No definite numerical relationship exists between a species and its characteristic mutants. For example, in the year 1896 there appeared 377 mutants and 8,000 of the original type (*lamarckiana*). In 1895, 14,000 *lamarckiana* were counted with only 334 mutants. In general, however, it might be said that the greater the number of plants and animals being raised, the more likely is it that there will be mutations.

4. No relation seems to exist beween a mutant and the usual or normal variation. During the entire term of experimentation, the parent plant, as well as the mutants derived from it, showed characteristic variations in size and shape of leaf, stalk, etc. The fluctuating variations were considered in the first part of this chapter.

5. These unusual variations, or mutations, breed true to the newly originated type.

6. Identically the same mutant may appear in a great number of instances.

7. Mutations may occur in both positive and negative directions.

8. Natural selection weeds out all unfit mutants which arise in the wild, and perpetuates those which are adaptable to their environment.

Examples of Mutation.—A clearer conception of these facts, as well as of the practical importance of mutations, will be gained by a study of some recorded instances. A number of cases in which marked changes have been wrought in plant and animal life, thru this one factor, have been placed on record. It is a well-known fact that some breeds of cattle have long horns, which, being undesirable, must be removed by dehorning. Other breeds of cattle never grow these weapons of offense and defense. The origin of this hornless type of cattle is recorded in at least one well known instance. In the year 1889, on a ranch near Atchison, Kansas, an animal was born which never produced horns. Clearly, this animal must have been a mutant—a discontinuous variation—but, of course, it was not recognized as such at the time. By the successful breeding of this animal, the race of polled Herefords was established.

Downing narrates the following instance of mutation—the origin of a disease-resisting cabbage: "The truck-garden re-

FIG. 67. An achondroplastic dwarf can perform some unusual feats owing to the fact that the bones of the body have developed more normally than those of the limbs.

gion about Chicago is the greatest cabbage growing area in the world. Many of the farmers of northwestern Indiana, northern Illinois, and southern Wisconsin have devoted themselves exclusively to this one crop. Within a generation, however, the region has been invaded by a very serious disease, the "yellows," that attacks the young plant, withering and killing it. Fields that formerly produced tons of cabbage now yield absolutely none, and the virus seems to remain persistently in the soil even after other crops have been grown for several years. The plant pathologist of the University of Wisconsin was called in to help solve the trouble. The situation was studied for several years without avail. Then in the midst of a fifteen-acre field two lusty cabbage plants were found with well formed heads, although all of their companion plants had succumbed to the dread disease. It seemed to the farmer a pitifully small crop, but to the expert a very hopeful one—two plants, at least, that were disease-resisting. Seed reared from these produced similar healthy cabbages on farms that had been unable to get a crop with the ordinary cabbage for years. And now with this new disease-resistant variety the region is returning with assurance to its very profitable industry."

A characteristic mutant of the common beech is the purple beech. This is shown from the fact that the purple beech has appeared suddenly a number of times in widely separated localities. Double flowers appear as mutants from almost any flowering plant, and then breed true to this double type. Such cases have been recorded with primroses, roses, carnations, petunias, and others. The oaklike walnut (*Juglans californica* var. *quercina*) is another splendid example of plant mutation. "Shirley poppies" originated from a type of single red poppy. The Shirley poppy is very large and has a wonderful range of color.

The origin of the Ancon sheep was a mutation which occurred in Massachusetts. The progenitor of this entire race was a bow-legged, sagging-bodied, dachshund-like lamb which was born on the farm of Seth Wright in 1791. He had foreseen the necessity for a breed of sheep which would be unable to jump fences, so he developed the Ancons from his "mutant."

Davenport (1909) had the following to say regarding variations (many of which were mutations) in poultry: "During the past four years I have handled and described over 10,000 poultry of known ancestry. Of striking new characters I have observed many, some incompatible with normal existence; others in no way unfitting the individual for continued life.

In the egg unhatched I have obtained Siamese twins, pug jaws, and chicks with thigh bones absent. There have been reared chicks with toes grown together by a web, without toenails or with two toenails to a toe; with three, five, six, or seven toes; with one wing or both lacking; with two pairs of spurs; without oil-gland or tail; with neck devoid of feathers; with cerebral hernia and a great crest; with feather shaft recurved, with barbs twisted and dichotomously (divided into two subordinate

FIG. 68. Varieties of cabbage which are supposed to have arisen as mutants from the wild cliff cabbage (A). B. Broccoli (leaves and flowers both used). C. Kale. D. Kohlrabi. E. Brussels sprouts (lateral buds used). F. Common cabbage (a highly developed terminal bud). G. Cauliflower (flower buds used). (From Gager's "Fundamentals of Botany." Courtesy of P. Blakiston's Son & Co., Philadelphia.)

parts) branched or lacking altogether. Of comb alone I have a score of forms. All of these characters have been offered to me without the least effort or conscious selection on my part, and each appeared in the first generation as well-developed peculiarities, and in so far as their inheritance was witnessed, each refused to blend when mated with a dissimilar form."

In addition to the above examples, strawberry plants without runners; thornless roses; five-leaved, or nine-leaved clover; red sunflowers (Cockerell); seedless bananas; tailless cats, dogs, or fowls; varieties of cabbage (Fig. 68) and many other types of mutations, have come under our observation.

Kinds of Mutations.—Hugo de Vries classed mutations into three groups; namely, *progressive*, *regressive*, and *degressive*. Progressive mutations are distinguished by the fact that some new character has been added to the individual in addition to those already present. The possession of a sixth finger on the human hand is an example of a *progressive* mutation, providing, of course, that same is heritable. When a character that is usually present is wanting in the new individual, that individual is a *regressive* mutant. The absence of horns in cattle, and the absence of hair in mice or dogs, places them in the regressive class. *Degressive* mutants are those in which some ancestral trait, long since dropped from the characteristics of the race, suddenly crops out. The muscles which control the movement of the human ear have degenerated to such an extent that they have entirely lost their original function. Occasionally, however, an individual is born who is able to move the shell of his ear. Such a person might be considered a degressive mutant in this one respect.

Causes of Variation

> *"Our ignorance of the laws of variation is profound."*
> —*Darwin.*

Altho the above statement was made almost three-quarters of a century ago, it is more or less true to-day. The investigations of the many workers in this field have revealed many facts regarding the operation of variation, and many hypotheses have been advanced regarding its causes; but, the facts still remain obscure. Since variations may appear at any time (they themselves varying in amount and intensity), and since they never seem to follow any set principle, a search for the causes—until more facts are known—is in reality "a search for some unknown force in the misty field of biology."

Although progress along this line has been very slow, we have advanced beyond the interpretation of Darwin and the other early workers. With them, the explanation that "variation is the normal thing for an organism" was sufficient to explain all cases. Many considered variation axiomatic—no explanation being necessary. Lamarck contended that the causes of the phenomena of variation might be traced directly to environment. According to his view, a change in environment would condition a corresponding change of variation in any organism living in that environment. In other words, the environment modified the cells of the body causing a dissimilarity between individuals, when, under *exactly similar conditions* in life, they would be indistinguishable. It was further contended that these variations in the body (somatic) cells became so fixed as to be transmissible to the next generation.

The above conception of variation might be acceptable in a modified form if we eliminate the element which claims that these somatic changes are truly heritable. It is extremely unlikely that variations in offspring are produced in this manner. *Outside influences* in the environment may, however, affect the germ cells in such a way that variation may be the result (See Chapter XXIX).

During the last few years, biologists have been looking to the *cell* as the basis for the explanation of variation and a great many of the other phenomena of heredity. An intelligent knowledge of the relationships which exist between the various processes of fertilization and the germ cell should be gained, after which the subject of *causes of variation* will be reconsidered.

CHAPTER XIV

THE CELL AS THE CARRIER OF HERITAGE

Introduction—Facts about Heritage—Ontogeny and Phylogeny—The Cell Theory—Differentiation of the Germ Cells—A Typical Animal Cell—The Method of Cell Division—The "Green" Germ Cells—The Ripening of the Female Cells—The Union of the Sperm and the Egg—Germ Cells of Birds—Germ Cells of Mammals—The Cell and Inheritance.

"The cell-theory must be placed beside the evolution-theory as one of the foundation stones of modern biology."

"Heredity is a consequence of the genetic continuity of cells by division, and the germ cells form the vehicle of transmission from one generation to another."

—E. B. Wilson.

Introduction.—Resemblances between parent and offspring have been a matter of common observation for centuries. The average child would be considered foolish were he even to speculate upon the probability of a hen's egg hatching into a duckling. It is further universally understood that the eggs from Plymouth Rock chickens will hatch Plymouth Rocks and not White Leghorn chicks. Until recent years, these simple facts were considered purely axiomatic. Some investigating mind noted the fact that the hen which hatched and cared for a brood did not influence the color and make-up of her chicks unless they were derived from her own eggs. The factors which determined the characters of the chicks were, therefore, located in the eggs from which they were hatched. The question then arose as to the nature and the location of this "something," since very minor, if any, differences could be observed between the eggs of distinctly different breeds of poultry. It was also observed that the eggs from a Plymouth Rock hen which had been mated with a male bird of some other breed did not give a pure breed of Plymouth Rock chickens. Since this indicated that the father also plays an important part in the rôle of heredity, some one began to search for the male cell which corresponds to the eggs of the female. Such was, in all probability, the general method of observation, and the reason which prompted the biologists to turn their microscopes upon the mysterious "Carriers of the Heritage"—the reproductive cells. The problem was at first extremely puzzling as no one could conceive that microscopic cells, such as the sperms [1] and the eggs, could carry enough of that peculiar "something" to represent each of the many characteristics of the individual. An attempt to enumerate the different characteristics of any individual will show that the factors in the germ cells must be very numerous. For example, a different "something" or a combination of "somethings" in the human ovum or sperm was thought to stand for red hair, a long nose, large cheek bones, eye color, large feet, a high temper, low mentality, small stature, etc., etc.

This type of investigation formed a basis for the study of several problems in the development and the life of the individual (Ontogeny). For years, men had concerned themselves only with the life and the development of the race (Phylogeny) and had considered ontogeny as being self-evident. It thus happened that the knowledge of the practical laws of heredity, especially as applied to the human race, lagged far behind the other phases of biologic research. The advancement of the cell theory stimulated an interest in the laws pertaining to the development of the individual, and, when once begun, the knowledge gained was of sufficient interest and value to receive hearty support from all the leading biologists, as well as from a large percentage of the people in general. The present state of advancement of knowledge along the various lines of he-

[1] For brevity the author prefers to follow custom by using the terms sperm and spermatozoön synonymously although technically the former refers to the seminal fluid and the latter to the germ cells.

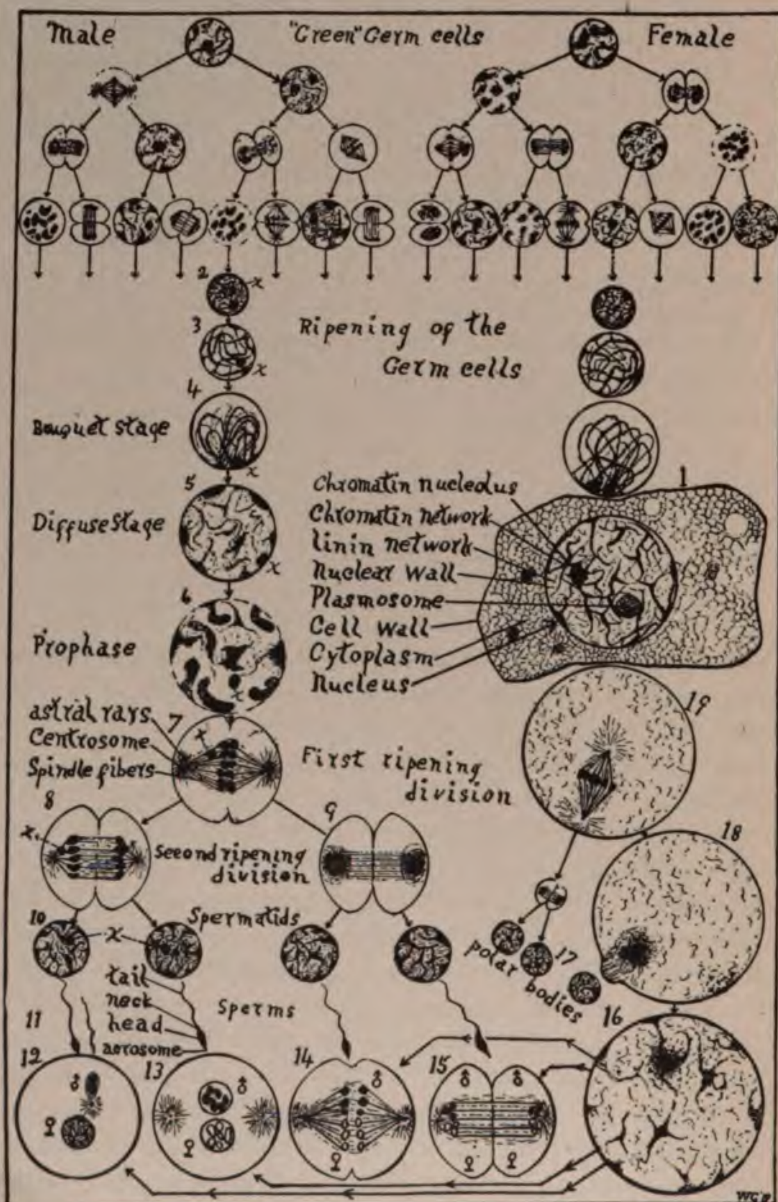
redity, and especially along the lines of cytology, is due to the method of direct observation with the microscope, assisted by valuable experimentation and analysis of statistics.

The Cell Theory.—The cell theory is the foundation upon which rest many of the explanations of biologic phenomena. In order to gain a clear idea of this theory, it becomes necessary, at this point, to trace the history of the cell. The cells, as the units of structure, their composition, varieties, the manner in which they were discovered, and how they obtained their name, have already been discussed in an elementary manner (Chapter VII). After the cell itself had been discovered, next came the discovery of the nucleus. Schleiden was responsible for the first statement that cells were the units of structure in all plants. But he held many erroneous ideas regarding cell functions which have since been cleared up. Schwann followed Schleiden in extending the cell theory to include animal tissues. Both Schleiden and Schwann held that the cell-wall was the important part of the cell. Their theory was also weak from the standpoint of the origin and the growth of cells. Our knowledge of cells has been so greatly enlarged since the time of these two pioneer investigators, that we now know a great many *facts* about their functions and life histories. We are also beginning to peer into the mysteries of the cell as the carrier of the heritage as well. Our conceptions of the physiology of cells have been completely transformed since Schleiden and Schwann made their observations. We know that cells do not arise by any process such as that followed in the formation of inorganic crystals. Cells arise only from other and preëxisting cells. The cell wall is not the all-important factor, since the seat of life has been proved to lie in the protoplasmic substance of the cell-body, particularly the nucleus.

E. B. Wilson of Columbia University, one of the foremost cytologists of the country, said: "It was the cell-theory that first brought the structure of plants and animals under one point of view, by revealing their common plan of organization.

. . . It was the cell-theory again which, in the hands of Goodsir, Virchow, and Max Schultze, inaugurated a new era in the history of physiology and pathology, by showing that all the various functions of the body, in health and in disease, are but the outward expressions of cell activities. And, at a still later day, it was through the cell-theory that Hertwig, Fol, Van Beneden, and Strasburger solved the long-standing riddle of the fertilization of the egg and the mechanism of hereditary transmission."

Differentiation of the Germ Cells.—The maxim of Virchow (1855), "*omnis cellula e cellula*" (all cells come from cells), after being tested from all angles for more than three score years by the world's most painstaking investigators, has come to be universally accepted. Since, according to this theory, all the cells of the body must have originated from a single cell, and further, since this single cell can be traced back to the ovaries and testes of the parents, it is obvious that there are two types of cells. These are referred to as *somatic* cells and *germ* cells. The somatic cells are the cells which are found in our muscles, nerves, bones, and skin; the germ cells are found only in the ovaries and testes, and are those which perpetuate life. The former, which constitute the body tissues, live thru a life cycle and then die, while the latter live an immortal life. According to this conception, the individual is composed of millions of sub-branches from one single off-shoot of the germ cell. This might be illustrated by a vine which sends up annual shoots. The plants themselves die, but underneath the surface the roots continue to send up new sprouts each year. If a leaf on the plant or an arm of the individual be cut off, the race is not affected; but, sever the whole shoot before it reproduces and the race stops—in plants the underground root may or may not live. Thus each individual germ cell constitutes only a small link in the chain of life flowing from the ovaries of Eve to the final destruction of the human race. It is interesting, in this connection, to note that from the standpoint of somatic cells, the father is older than the son;


Male
"Green" Germ cells
Female
Ripening of the
Germ cells
Bouquet stage
Diffuse Stage
Prophase
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Cell wall
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Centrosome
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FIG. 69. Diagram Illustrating the Maturation of the Germ Cells. The small active cells at the top of the plate are known as spermatogonial (in the male) and oogonial (in the female) cells. They represent a few of the many divisions which must take place before a single germ cell of a tiny embryo can become the large reproducing testis or ovary of the adult.

FIG. 1. A typical animal cell.

FIGS. 2 to 6, inclusive, and the corresponding figures to the right, show some of the more important steps in the growth periods of the ripening germ cells.

FIGS. 4 and 5 show the stages in which the germ cells of the mule and other hybrids first begin to show indications of abnormality which result in the final destruction of the cell.

FIG. 7. First ripening division of the male germ cell. (First spermatocyte division.)

FIG. 19. Corresponding division in the ovary. (First oocyte division.)

FIGS. 8 and 9. Second ripening division. (Second spermatocyte division.)

FIG. 18. Second oocyte.

FIG. 10. Spermatids (first two with, and the second two without sex chromosomes).

FIG. 11. Mature spermatozoa.

FIG. 16. The single large mature egg.

FIG. 17. The three small eggs (the polar bodies) which never mature.

FIGS. 12, 13, 14 and 15 represent the possibility of the single egg (Fig. 16) being fertilized by any one of the four "brother" spermatozoa shown in Fig. 11. Since the first two contain the sex chromosome, a union of either of these with the egg would result in female offspring (Figs. 12 and 13), while the other two would produce males (Figs. 14 and 15).

FIGS. 12, 13, 14 and 15 also show that the reduced number of the chromosomes brought in by each parent cell (Figs. 12 and 13) unite to form the normal number for the offspring (Fig. 15), and that the chromosomes from each parent (Fig. 13) are equally distributed in every offspring (Fig. 15). (From *American Journal of Veterinary Medicine,* by the author.)

but, if the continuity of the germ cells be considered, the son is one generation older than his father. The somatic cells in the hand of the father, for instance, are older than those of his son. On the other hand, the germ cells of the son which must have been derived from the father, are, as a consequence, one generation older.

A Typical Animal Cell (*1, Fig. 69*).—The germ cells are usually much larger than the somatic cells and are thus used as a basis for general study. All cells are made up of a nucleus enveloped by a more or less viscous substance, the cytoplasm. The substance inside of the nucleus is spoken of as the nucleoplasm or karyoplasm. In the nucleus there is usually found a heavy network (chromatin-network) and a dense mass of chromatin, the chromatin-nucleolus. Since the hereditary factors are located in this chromatin material, it is important that we understand the behavior of this peculiar substance. Its function will be discussed later. There may also be found a finer network of achromatic substance (linin-network), and sometimes a spherical mass, the plasmosome, of the same material (Goldsmith, '16). The nucleus together with the cytoplasm constitutes the protoplasm.

The Method of Cell Division.—After the cell has reached a certain stage of growth, the chromatin-network begins to condense at various points in the nucleus—usually near or in contact with the nuclear membrane (5, Fig. 69). These aggregations become more and more definite and individualized until they each assume a compact and characteristic form (prophase stage, 6). These newly formed bodies are called chromosomes and are uniformly characteristic of the species in which they are found (Fig. 70). They vary from two in a thread worm to 1600 in certain radiolaria. A small body (the centrosome, 7) from which radiate cytoplasmic lines (astral rays, 7), now appears on either side of the nucleus. The nuclear wall is then destroyed partly by the removal of the chromatin (Goldsmith, '16). Prominent fibers (spindle fibers, 7) now connect these two points as centers and force the chromosomes into a median position, thus presenting a typical spindle (metaphase condition, 7). The chromosomes now divide lengthwise and one-half of each passes to opposite poles of the spindle. While the chromosomes are on their way to the poles (anaphase stage, 8, Fig. 69), the entire cell begins to divide. This continues until after the chromosomes have reached the spindle (telophase, 9, Fig. 69), when the two

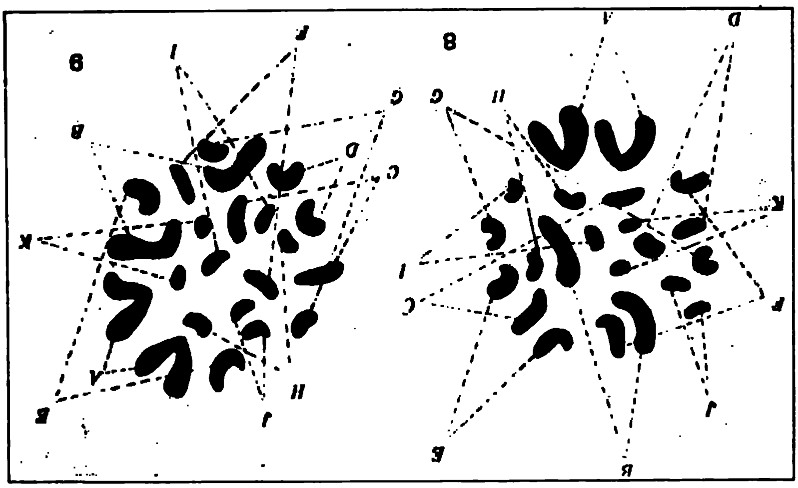

FIG. 70. Chromosomes of the tiger beetle. The shape and size of the chromosomes (the bearers of heritage) vary from large and asymetrically armed V's (A in figure) to very small spherical bodies. This figure also shows that definite pairs of chromosomes are found in the cells of every individual. (From *The Journal of Morphology*, Vol. XXXII, by the author.)

daughter cells are completely separated. The chromosomes of each daughter cell now reassume their early "woolly" appearance and gradually pass into the network condition, while the nuclear membrane and the other parts of the cell are being reconstructed in preparation for the next division.

The "Green" Germ Cells (*Spermatogonia and Oögonia*). —The processes in cell division are essentially the same, whether somatic or germinal. However, since the former cells are smaller, the component parts are more compact and not so readily differentiated. From a very early embryonic condition, until near the time the animal is capable of reproducing, the large cells which were set aside for this purpose gradually increase in number by the above method of cell division. (Fig. 69, " 'Green' Germ Cells.") So long as the cells of the ovaries and testes continue the simple process of multiplication, no marked change is noted in the life of the child. On the other hand, when the germ cells begin to ripen; that is, begin the formation of mature sperms and ova, the entire individual begins to undergo marked changes. When the human race is under consideration, this period of transformation is spoken of as the "period of adolescence." It is interesting to note that many who speak so glibly about the "period of adolescence" have no conception of the real biologic significance of this developmental phenomenon.

When the animal is near maturity, a number of these cells seem to lose their division energy. They then enter a quiescent or rather a ripening stage in preparation for the great function for which they were ordained; namely, that of reproduction. This stage is spoken of as the *growth*, or *maturation* period of the germ cell. The author has investigated one form (the Tiger Beetles, *Jour. Morph.* V, 32) in which he is able to predict by the appearance of the cells those which have about lost their division energy and are ready to undergo maturation. This process might be compared to the ripening of an apple. The apple grows for a number of weeks until it reaches a certain stage when it ceases to grow and begins to ripen. Although the size is not materially changed during the ripening process, internal physiological changes are taking place very rapidly.

The Ripening of the Germ Cells (*The Maturation Period*)

A. The Growth Stage: After an early germ cell has lost its division energy and is ready for ripening, the two daughter cells resulting from the last division fail to reconstruct as usual to form another division spindle. The nuclear wall is usually reformed but the nucleus itself is filled with a dense fibrillar, but somewhat granular network (2, Fig. 69). Among this homogeneous network, there are ofttimes found one or more compact bodies resembling the chromosomes (2 to 10 inclusive). In fact, we have demonstrated conclusively that these bodies have persisted as distinct individuals from the chromosomes of the earlier divisions, all others having been spun out to make the new network. These dense bodies never break up as do the other chromosomes, but remain as *independent* elements while the cell is ripening. They are called "sex-chromosomes," or better, "female producing chromosomes" since, as will be shown presently, they are, at least, associated with sex-production.

As the cell and nucleus continue to grow, some very interesting changes take place in the fibrillar network. Typically, it forms into as many long strands as there were chromosomes in the earlier stages, not considering the sex-chromosomes (3, Fig. 69). The ends of these dense threads are now mysteriously drawn to one region, usually against the wall of the nucleus. Since they seem to be floating in a nuclear sap, the median parts of each thread swing out into the nucleus, forming a bundle of very clear loops (4, Fig. 69). The cytologist calls this the bouquet stage of the ripening cell. The female producing chromosome is usually in the thickest part of this bundle. As these loops decrease in size, presenting a very compact condition (synizesis), they are ofttimes observed to pair (synapsis). Since each loop represents a chromosome, the number of these bodies is now evidently reduced one-half, excluding the mysterious sex-chromosome. This reduction in number is very significant, since it is necessary in order to keep the number constant for each species. It will readily be seen that when *one-half the normal number of chromosomes* of each parent unite in fertilization, the daughter cell will possess the normal number of the parents—the daughter the number of the mother, and the son the number of the father. Should this fortunate process not happen, and the mother and father pass to the child their normal number instead of one-half, our cells would soon be bursting with chromosomes and, thus, future reproduction would be impossible. After the process of pairing has taken place, the chromatic fibers break up and are again faintly distributed throughout the nucleus (5, Fig. 69). As the cell still continues to grow, this faint chromatin material collects into as many aggregations as there were pairs of fibers (6, Fig. 69). These masses now condense and form the chromosomes for the first of the two ripening divisions (7, 8, and 9, Fig. 69). It must be remembered, however, that the number of chromosomes is now only one-half [1] the former number exclusive of the sex-chromosomes. We express this as $\frac{1}{2}n + x$; that is, one-half the normal number plus the sex-chromosome.

B. The Two Ripening Divisions:[2] The germ cells now undergo two divisions, differing somewhat from those discussed earlier. The number of chromosomes in these divisions is one-half plus the sex-chromosome which had no mate in the growth period. This female producing body still (in most forms and in all domestic animals) does not associate with the other chromosomes but takes its position at one side of the spindle and in advance of its neighbors (7 and 8, Fig. 69). All the autosomes (common chromosomes), divide as usual and the respective halves pass into the daughter cells. *Since the sex-chromosome passes undivided to one cell, we have two different types of cells produced.* It will be shown later how the one with the extra body (8, 10, and 11, Fig. 69) will produce a female, while the one without this important chromosome (9, etc., Fig. 69 and their derivatives) will give a male. In a few forms (not in domestic animals), the sex-chromosome divides in the first but passes bodily to the daughter cell in the second division, the resulting process being the same.

These two types of cells now divide once more, all chromo-

[1] This statement does not apply to certain parthenogenetic forms.

[2] For a consideration of Tetrads and Equational and Reductional division see more technical works.

somes taking part in the process, and then pass into another state of reconstruction. These reconstructing cells are now called "spermatids" (10, Fig. 69) and are transformed directly into spermatozoa. This process of transformation is very complicated but has been worked out to the most minute details. The most important point to consider here is the fact that all the chromosomes, except the female-producers, again pass into the fibrillar condition. In some forms, the sex-chromosomes can be followed step by step into the head of the mature spermatozoön. (See Goldsmith, '19, Fig. 69.) The behavior and fate of the female-producing chromosome should be clearly understood. Since, in our illustration (7, Fig. 69), this body has moved by the law of chance to the left side of the cell, the new cell formed from this part of the mother cell will possess it; the cell formed from the other side will be without it. Therefore, the first two spermatids shown (10, Fig. 69) and the first two sperms (11, Fig. 69) will possess this female producing element; the last two spermatids and the last two sperms (same figures) will be without it, since they came from the cell represented (9, Fig. 69), and thus from the right-hand half of the cell shown in 7.

A Typical Ripe Male Germ Cell.—A mature spermatozoön (Fig. 69, 11) consists of a head, neck or middle piece, and a tail. At the forward point of the head there is a small sharp body, the *acrosome*, by means of which the sperm bores its way into the egg (16, Fig. 69). The chromatin material is located in the more or less elongated head. The tail, which is surrounded by a thin membrane (tail envelope), is an organ of locomotion and is usually broken off as the sperm enters the egg (12, Fig. 69), its function having been completed. The structure and behavior of the spermatozoön is usually considered as presented in this paragraph. However, the author is inclined to think that more extensive investigation into the metamorphosis of spermatids would reveal facts somewhat contradictory to the present belief. In the formation of the spermatozoa of the tiger beetle (Goldsmith, '19), the chromatin material seems to elongate to form a part of the tail of the sperm.

The Ripening of the Female Germ Cell.—The development of the female cell differs only in minor details from that of the male. In ripening, however, each division produces daughter cells extremely different in size. The larger ones (16 and 18, Fig. 69) continue to mature and prepare for fertilization, while the smaller (the polar bodies, 17, Fig. 69) are absorbed. It is readily seen from the plate that three-fourths of all the eggs perish at this point, and that from the same number of "green" cells, four times as many sperms are produced as there are eggs. This is very fortunate as the sperms must undergo much more hazardous experiences, in reaching their destination, and, thus, are more liable to destruction than the eggs.

Union of the Sperm and the Egg.—After the sperm enters the egg (12 to 14, Fig. 69) the middle piece, which carries "the active center of cell division," *the centrosome*, turns in the direction of the egg nucleus (12, Fig. 69) and a joint spindle between the male and female cells is formed (13, 14, and 15, Fig. 69). The most important consideration in this process is the fact that *the reduced number of chromosomes brought in by each parent cell now unite to form the normal number for the offspring* (15, Fig. 69). Furthermore, *the chromosomes from each parent are equally distributed in every daughter cell.* Prof. Morgan introduces chapter three of his book, "Physical Basis of Heredity" (1919), with this decided statement: "One of the most secure generalizations of modern work on the cell is that every cell of the individual contains a *constant number* of self-perpetuating bodies (called chromosomes) half of which are traceable to the father and half to the mother of the individual." A study of the diagrammatic Figures 13, 14, and 15 (Fig. 69) will make this point clear. Since the solid black chromosomes represent the haploid (reduced, or one-half the normal number) number of male chromosomes and the open face chromosomes the haploid female number, it is evident that both of the newly-formed cells (15, Fig. 69) are the recipients of an equal amount of father and mother chromatin material. Furthermore, since this chromatin material is the bearer of individual characteristics, the mother and the father have an equal part in supplying the child with hereditary traits. This line of microscopic investigation has proved to be the final deathblow to the old theory that the child inherits from the mother more characteristics than from the father. This, too, destroys all possibilities of so-called "birthmarks" and the whole category of such parental influences. (See Chapter XXVIII.)

Germ Cells of Birds.—The cells of the birds are very small, and the constituent parts are so crowded and irregular in shape, that a study of these forms is very laborious. Guyer, ('16), for example, published the results of over ten years' study on the sperm formation in the common rooster. Here he finds, in addition to the mass of irregular chromosomes, a large curved sex-chromosome, which stands aloof from its neighbors while on the first maturation spindle. Since the early germ cells of the chicken have sixteen ordinary chromosomes plus this sex-element, and, since this element neither conjugates in the ripening process nor divides in the first ripening division, one daughter cell has eight ordinary chromosomes, while the other possesses, in addition to these, the large curved sex-element. The ordinary chromosomes of each daughter cell now pair and fuse, leaving four in one and four plus the sex determiner in the other. All chromosomes again divide in the second division, and thus it is brought about that two classes of cells are formed containing four and five chromosomes respectively.

In the hybrid pheasants, and hybrid guinea-chickens, the normal development continues up to synapsis when the chromatin fibres are unable to unravel from the synaptic knot (See 4 and 5, Fig. 69). The mass of chromatin remains attached to the nuclear wall and then either disintegrates, or abnormal spermatozoa are formed which are incapable of fertilization.

This clearly accounts for the fact that the breeding of such hybrid birds is an impossibility. (See Chapter XVII.)

Germ Cells of Mammals.—One of the first mammals to be studied was man. The cells of man represent one of the most problematical cases of cell study. The number of somatic chromosomes has been variously counted from 24 to 38 (Fleming 24; Farner, Moore, Walker 32; Wieman 33 to 38), while the number in the testes are given as 47 by Winiwarter and as 22 by Guyer and Montgomery. Winiwarter obtained his data from a white man, while Guyer and Montgomery worked on negro material. In the case of Winiwarter's work on the germ cells of the white man, the numbers in the maturation divisions are 23 and 24, while Guyer shows that the corresponding numbers in the negro are 10 and 12. If the works of the last two investigators stand the test of future research, we may have a very definite and substantial criterion by which to segregate the white and black races. Hoy (1916) suggests that the variations in the number of chromosomes in the different individuals studied might represent intermediate hybrids between the black and the white races.

Furthermore, Guyer finds in man two sex-chromosomes which do not associate with the other elements on the first maturation spindle but pass bodily to one pole, thus giving 10 chromosomes in one daughter cell and 12 in the other. The ten common chromosomes now unite, two by two, giving second division cells and thus mature sperms with 5 (5 double) and 7 (5 double plus the two sex-chromosomes) chromosomes respectively. Assuming the woman (negro) to have 24 chromosomes—that is 12 after they have been reduced for fertilization—we can readily predict the sex of the offspring of each cell. If the sperm carrying the twelve chromosomes (Fig. 69, 11, first two sperms) should come into contact with the egg (16), a new cell (12 and 13), and later an embryo having 24 chromosomes would be formed. This would of course be a female, since the male has only 22 chromosomes; the union of a sperm having only 10 chromosomes and an egg would result in an embryo of 22 chromosomes, a male. These facts might be presented thus:

Chromosomes of father		Chromosomes of mother		Chromosomes of child
10	+	(10 + 2x)	=	(20 + 2x)=22 (Boy)
(10 + 2x)	+	(10 + 2x)	=	(20 + 4x)=24 (Girl)

Wodsedalek (1913) has clearly demonstrated the presence of eighteen rod-shaped chromosomes in the male pig and twenty in the female. Two of these chromosomes in the male cells usually stand apart from the others. They remain very conspicuous throughout the ripening stages and in the first division stand quite aloof from their neighbors, passing undivided to the "female daughter cell." In the second ripening division, they divide as other chromosomes, giving eight for one cell and ten (8 common and 2 sex-chromosomes) for the other. The common chromosomes fuse at this point, as in man, to form half the number of double elements, but this has no effect upon the final result. If the cell with eight meets a female cell, all of which have 10 after ripening, the result would be a male pig, while if the cell with the two female producing chromosomes meets a female cell the result would be a pig with 20 chromosomes, which is to say, a female.

Chromosomes of male pig		Chromosomes of female pig		Chromosomes of offspring
8	+	(8 + 2x)	=	(16 + 2x)=18 (Male)
(8 + 2x)	+	(8 + 2x)	=	(16 + 4x)=20 (Female)

It is interesting to note that in the pig and many other forms the mature spermatozoa are of two distinct sizes, representing the two sexes—the female-producing being the larger, due to the presence of the two extra chromosomes.

Except from the standpoint of the number of chromosomes, the method of sperm formation in the horse is almost identical with that of the pig. In the horse, there is only one female determining chromosome, which behaves as the two in the pig. The number in the green cells of the stallion is 37, representing two types of sperms with 18 (9 double) and 19 (9 double, 1 single) chromosomes respectively. According to these figures, the mare, whose germ cells have never been examined, should possess 38 chromosomes. This assumption is based upon the following fertilization formula:

Chromosomes of stallion		Chromosomes of mare (assumed)		Chromosomes of colt
18	+	(18 + x)	=	(36 + x)=37 (Male)
(18 + x)	+	(18 + x)	=	(36 + 2x)=38 (Female)

Further consideration might be given to the general methods of germ cell formation and fertilization in other animals but the above discussion will suffice to show the general processes involved.

The Cell and Inheritance.—The facts regarding the reproductive cells are becoming so important that very few subjects in the fields of evolution, heredity and eugenics can be considered without a knowledge of them. Not many years back, the biologists never for a moment considered that the facts of the cell theory were as vital to an understanding of heredity, variation and mutation, as they really are. Neither the expert technical breeder of plants and animals nor the practical agriculturist considered the work of the cytologist of any value in their fields. In like manner, few euthenists, even at the present time, recognize the fact that the cell theory forms at least a secondary key to their success. Many are coming to realize that *inheritance* is a vital factor in dealing with various social problems, but it seldom occurs to them that *the explanation of the facts of heredity may be based upon the knowledge of the cells.*

The above discussion of the maturation of germ cells and the part played by the chromosomes, in addition to familiarizing the reader with the cardinal points of cellular behavior, should suggest the importance of the cell in sex determination and in other problems pertaining to heredity.

It was found in discussing the chromosomes as related to sex, that sex is not a matter of guess work, but rather a definite result following a definite cause—the behavior of the sex elements. In general, the offspring which received the smaller number of chromosomes would be a male; the one which received the greater number would be a female. Since the chromosomes play such an important part in the determination of sex, and since sex is a matter of heredity, is it not here that we may look for the explanation of all other hereditary phenomena? It is the chromosomes, then, which contain the mysterious "something" which determines [1] the characteristics of the individual.

[1] Those who are directly interested in the technical side of this problem should familiarize themselves with the controversy regarding the importance of the cytoplasm in heredity and development. See works of Boveri, '01; Baltzer, '09; Schraxel, '11; Herbst, '09; Conklin, '10 and others.

CHAPTER XV

CAUSES OF VARIATION

Lamarck—Weismann—Chromosome Basis for Variation—Amphimixis—Internal and External Influences upon Somatic Variation.

"The fine art of the horticulturist is seen in the selection and fixing of the variations produced by crossing and hybridizaton. While most of the forms thus obtained are worthless, a few will show decided advances. Often as much progress may be made in a single cross or hybridization as in a dozen or even a hundred generations of pure selection."

—*Jordan and Kellogg.*

A few years ago, a consideration of the problems of variation would have involved only a general discussion of observed facts together with various hypotheses regarding them. Lamarck, for example, claimed that changes in plants and animals depended entirely upon the direct influence which their environment had upon them. He assumed that should a plant or an animal be placed in a favorable environment, and be permitted to live there year after year, the favorable effect upon each individual would be transmitted to its offspring, and thus, a sturdy race would be produced. It has been noted that Darwin himself considered the direct effect of environment as the principal cause of variation. The substance of this conception might be summed up in the following statement: *The somatic cells are modified by external conditions and in turn change the constitution of the germ cells.* Since the germ cells give rise to the new individual, that individual will possess the parental modifications. In striking contrast to this belief, Weismann (1834-1914) set forth a new idea in which he assumed that the changes which caused individual as well as racial variation were ***first brought about in the germ cells*** and ***secondarily*** in the body cells. From this time onward, the biologists have turned their attention to the ***cell*** for a solution of the puzzling problem of variation.

FIG. 71. A double-kitten. This specimen shows a type of abnormal development of the egg during the early stages. Such double monsters may be found throughout the animal kingdom, showing that embryological development is uncertain. (Photographed from specimen—Southwestern College.)

One of the most important considerations relative to cellular behavior as a factor of variation might be presented by turning back to figure 69. During the process of maturation of the germ cell, it was shown that the number of chromosomes was reduced one-half before fertilization in order that the offspring may not have twice the usual number. The father and the mother each furnish one-half their number of chromosomes in order that the cell from which the future child is to be formed may possess the correct number. Should exactly the

Fig. 72. Radiograph of the double-kitten shown on the preceding page.

same chromosomes, carrying the same characters, unite during two successive processes in the formation of two individuals, these children would be identical in every imaginable respect.

Since the number of characteristics is so great, this would be next to impossible. In very rare cases of "identical" twins, the two individuals receive an unusually large number of characters of the same constitution. However, it must be noted that identical twins are supposed to be formed from a single egg—each half of the egg at the two-cell stage separating from the other and forming a distinct individual (Figs. 71, 72 and 73). Common twins result from the fertilization of two separate eggs. This combination of maternal and paternal chromatin makes the possibility of identical children, thru chromosome combinations, even more remote. Just as the twenty-six letters of the English alphabet are capable of being combined into hundreds of thousands of words, the chromatin in the human egg and sperm may be united in countless combinations of characteristics. A compound cell, one-half of which is paternal and the other half maternal, will naturally differ from either parent, because, in it, the characteristics of both are blended or stand out in combinations. This process of uniting two sets of hereditary factors of quite different origin is called *amphimixis* (Weismann) and is held to be one of the most effective means of producing variations and unusual combinations of characteristics.

According to the principle of amphimixis, *the greater the differences in the two lines of germ plasm, the greater should be the variation of the offspring.* Actual breeding establishes the truth of this assumption and lends strong support to Weismannism. However, attention should be called to the fact that the principles as set forth by Weismann have received some modification and much extension. Perhaps the most important line of development in this regard is the correlations that have been made between Weismannism and Mendelism. It seems quite conclusive from the great mass of growing evidence that these recombinations (amphimixis) conform strictly to the Mendelian Laws of inheritance, which are considered in the following chapter. This fact gives the breeder much more hope for progress, since it puts him in a better position to make wise selections of known favorable material in both plants and animals.

Our knowledge of amphimixis, or germinal recombinations (including extreme cases of hybrids), is growing by leaps and bounds. In fact, many cases which have been cited as mutants are now known to be hybrids or offspring from mixed races,

FIG. 73. A type of identical twins. The fact that these specimens were nourished by the same umbilical cord shows that they are identical twins, having been formed in the same embryological membrane. It is supposed that identical twins are formed by a complete cleavage of the egg during early development. Such double-monsters were possibly formed by a less complete division than is the case with the usual identical twins which are normal at birth. (Photographed from specimen—Southwestern College.)

many of which can be explained on the basis of Mendelian segregation (See Chap. XVIII). One very striking example is found in the records of Darwin of a "sport" (mutant) lamb which appeared from a merino mother (1826) and which gave rise to a breed of sheep whose fleece was much superior to that of the original breed. It was later shown that this lamb was a hybrid between two separate breeds. In view of recent investigations, it behooves us to be very cautious in order that we may not overstate the importance of mutation to the practical plant and animal breeder. Cases that appear to be examples of mutation should be recorded as such only after the most rigorous scrutiny in order to ascertain whether or not it is a complicated example of amphimixis. Pearl himself suggested that his supposed "mutation" in egg production might come under the Mendelian Law.

From the year that De Vries announced his results with the evening primrose, critics have assumed his original plant (*Œnothera lamarckiana*) to be a mixed form. If this were the case, the various forms (See Chap. XIII) which he called "mutants" would merely have been new combinations, which perhaps would fall in line with Mendel's work. For some time, interest in this subject waned but a new group of opponents are now challenging these "mutations" of De Vries which form the basis for the mutation theory of evolution. Altho it seems to have been shown quite recently that two of these mutants arose as *factor* mutants and three by a departure from the usual number of chromosomes—which, of course, would be true mutations—data seem to be accumulating to show that other forms arose by slight hybridization or amphimixis. Regardless of the final result of this line of investigation, the mutation theory has given great impetus to the study of experimental evolution, the benefits of which have been far-reaching in scope. No human being, at least in the civilized countries, has been exempted from the benefits which have been derived from a study of the many types of variation. Who has not profited by the improvements that have been made in cattle, hogs, sheep, grains, vegetables, and fruits? Moreover, these "impractical" and indeed theoretical principles are destined to develop into even a more profitable type of work in various phases of practical agriculture.

Amphimixis may be presented in various stages of effectiveness, depending upon the diversity of the parents. *Parents which are almost identical in their characteristics would* *be the most likely to produce offspring similar to themselves; parents with somewhat different germ plasms will present correspondingly different offspring; those differing still more will produce sterile hybrids; and those of great diversity will not produce offspring at all.* It is the production of hybrids thru the principle of amphimixis which forms the principal basis of Luther Burbank's works.

In addition to the recombination of germinal material (amphimixis), individuals with new or changed characteristics undoubtedly appear suddenly without any perceptible cause. In other words, sudden germinal alterations (mutations) must take place. This is perhaps brought about by some environmental influence acting upon the germ cells more or less in accordance with Weismann's views. Certain workers have called attention to the fact that the germ cells might be changed in this direct manner by variations in their nutrition, and by other similar means. It is known that the germ cells receive their nourishment in the same manner as do the body cells—thru the blood circulation. Therefore, since it is easily observed that the body cells are influenced by external factors acting thru the circulatory system, would it not seem logical to conclude that the germ cells may be acted upon in the same way? Metcalf suggests that "variations in animals might be due to the conditions of nutrition of the germ cells from which they come."

In addition to nourishment, the blood may carry any poisons or other substances that may be in solution to the various tissues of the body, including the reproductive organs. By so doing, the germ cells might be acted upon thru "*induction.*" This peculiar condition is given consideration in a later chapter (XXVII) in which the "Inheritance of Diseases" is discussed. In the way of a summary, it should be noted that of the two ways of altering the individual—*somatic modifications* and *germinal alterations* or *recombinations*—the former probably renders but little, if any, effect upon the moulding of the race. This will be more evident from the numerous illustrations which will be given in Chapter XXIX to show that somatic modifications are but *transitory.*

It is a matter of common observation that plants vary in size and productiveness. These characters are often determined in the offspring by the germinal qualities of the parents. But, it is a very obvious fact that *environment* and *induction* play a very large part in *somatic variations* in plants. A bed of radishes may be noted in which the plants are of varying sizes, and in different degrees of health and sturdiness. The seeds may have been uniformly fertile; they may have been planted at the same time, and under ideal conditions; the plants may have all sprouted at practically the same time. Subsequent differences in temperature, moisture, and soil conditions largely account for the variations in the maturing plants. If the seeds were sown thickly, and should the young plants remain unthinned, a process of "*struggle for existence*" would take place in which the "*unfit*" would be crowded out or forced to lead a stunted existence.

The element of food must be a vital determiner of size and sturdiness in animals as well as in plants. In a favorable environment, plants and animals will develop normally; but if the environment changes in an unfavorable direction, they will develop abnormally or not at all. A return to the original environment will be conducive to the original normal development of the plant or animal, provided the change would not be too radical. *Identical* environments and internal physiological conditions would tend to produce *identical* results from *identical* strains.

CHAPTER XVI

HYBRIDIZATION

Hybridized Plants—Hybrid Vigor—Hybridized Animals—"Grading"—Dairy Cows—The Zebu-Hereford Hybrid.

Hybridized Plants.—The fact that a plant with new characteristics can be produced by crossing two allied species or varieties has been known for many years. Altho Kölreuter (1776), Gärtner and other workers of the Eighteenth and early Nineteenth Centuries observed a few facts regarding the results of such crosses, it remained for Darwin to formulate some vital principles which attracted the attention of the botanists and the commercial plant breeders. Perhaps the most valuable result obtained from the uniting of two foreign strains of characteristics is in the increased vigor of the resulting hybrid. By hybridizing certain plants and animals, man is able not only to materially extend the field of his activity but also to increase the annual production of farm products to the extent of millions of dollars. Hunter suggested that the new variety of potatoes which Luther Burbank succeeded in growing a few years ago "has already enriched the farms of this country about $20,000,000." Another one of Burbank's hybrids which has become well known is the *Climax Plum* which was originated by crossing the bitter Chinese plum and an edible Japanese variety. The "Plumcot," as the name might suggest, is a cross between the plum and the apricot.

It must not be concluded, as seems to be the popular impression, that Burbank is responsible for the majority of the work in the field of plant hybridization. Although he is adding immense wealth to our country by his "*trial and error*" method, a number of other workers whose names are but little known outside of the scientific world are patiently carrying on systematic experiments and are thus placing hybridization on a scientific basis. It is indeed the works of such investigators as East, Shull, Jones, Hayes, and scores of minor workers, which are laying the foundation for much more successful work in the future. The "*hit and miss*" method in which thousands of plants are destroyed before a single useful one is obtained is to be complimented only when supported by such a masterful hand as Luther Burbank, but it lends little stimulation to future plant breeders.

As in all other fields of investigation, the great need is a systematic knowledge of the laws and principles which are associated with and govern hybridization. These, so far as has been ascertained, are compiled most admirably in *Plant Genetics* (Coulter and Coulter, The University of Chicago Press) under the title of *Hybrid Vigor*. It seems quite pertinent to present a few of these principles.

"Darwin . . . states that crossing hastens the time of flowering and maturing and increases the size of the individual. He adds the very important fact that it is not mere crossing that gives the stimulus, but crossing forms that differ in the constitution of their sex elements; in other words, crossing between individual flowers on the same plant gives no advantage. . . . Shull's conclusions up to the year 1910 may be summarized as follows: His work was entirely with corn, and the conclusions contained some very significant points. 'The progeny of every self-fertilized corn plant is of inferior size, vigor, and productiveness, as compared with the progeny of a normally cross-bred plant derived from the same source.' In general this conclusion would be admitted by everyone, but it raised one question. It was known that when two races have been inbred for many generations they frequently 'run out,' gradually losing their vigor. In such a case a cross between the two races tends to restore the original vigor. The remaining question, however, is whether the same thing may be effected by a cross between two inbred races which have not run out but remain in normal vigor. Shull answers that hybrid vigor is exhibited when both parents are above the average condition as well as when they are below it.

"Another question which naturally arises is as follows: When these crosses are made it is of course the F_1 [first] generation that shows the hybrid vigor. If the F_1 generation is inbred, what is the status of the F_2 [second] generation with reference to vigor? Shull answers this question in the following general way. 'The decrease in size and vigor which accompanies self-fertilization is greatest in the first generation, and becomes less and less in each succeeding generation, until a condition is reached in which there is (presumably) no more loss of vigor.' . . . 'A cross between sibs (sister and brother) within a self-fertilized family shows little or no improvement over self-fertilization in the same family.' . . . 'A cross between plants belonging to two self-fertilized families results in a progeny of as great vigor, size, and productiveness as are possessed by families which have never been self-fertilized.' The conclusion from this is that inbreeding results in no permanent loss of vigor. A race may 'run out' if inbred continuously, but when crossed with another race it immediately seems to regain all the original vigor. It is as tho all germ plasm contains the potentiality of developing vigorous individuals. This potentiality, however, cannot express itself until the proper combination of conditions arises, and this proper combination seems to be connected with hybridizing.

"'Reciprocal crosses between two distinct self-fertilized families are equal in producing hybrid vigor. When reciprocal crosses are equal it immediately suggests Mendelian segregation. Is it possible that hybrid vigor may be explained in terms of Mendelism?' . . . In connection with this work East was undertaking to discover the nature of hybrid vigor. In what respects are such hybrids vigorous? In reply to this question East offers the following analysis of hybrid vigor. Primarily it is an increase and acceleration of cell division; in other words an increase in the power of assimilation. One can early observe a slight increase in the size of the cotyledons. The more rapid growth and earlier maturity of the seedlings is quite noticeable. Then one sees a distinct increase in the size of the roots. In the stem there is no increase in the number of nodes, but the internodal development is striking. Usually the stem growth is greater than the leaf growth, but the increase of the latter can be definitely traced. The size of the flower is usually not affected, nor is there any change in the size of small fruits, such as tobacco. In fleshy fruits, such as tomato and eggplant, there is a marked increase. On the individual plant there are distinctly more flowers and fruits, and in some cases separate inflorescences are longer, such as the ears of corn."

It has been noted from the above quotations that hybridization does not render the same result in the case of all crosses. In one cross a very vigorous and markedly different plant may be produced while in another no noticeable difference is obtained. In the case of hybridized tobacco, the vigor is reduced. This is due, in a measure, to the fact that this plant is a self-fertilizing species. It has been suggested by East and others that the differences in the results, obtained by certain crosses, are due to the dissimilarities in the genetic constitution of the parents. That is, if the characteristics of the plants which are to be crossed are quite diverse, the hybrid will be more vigorous than if the parents are quite similar. Coulter and Coulter summarize East's conclusion regarding this point as follows: "*Hybrid vigor is proportional to the number of factors in which parents differ.*"

Hybridized Animals.—It is extremely interesting to note that the principles which underlie hybridization of plants do not seem to apply with equal force in the animal kingdom. Altho a number of cases are cited in which crosses between animals result in quite divergent forms with increased vigor, it is claimed by many zoölogists that *a loss of vigor is the general rule.* This lack of agreement between the botanists and the zoölogists may be due, to a certain extent, to the fact that

A

B

C

FIG. 74. The result of grading scrub dairy cattle with pure-bred Holstein-Friesian bulls. A scrub cow from a point in Arkansas where no thoroughbred stock had been used was mated to a thoroughbred Holstein-Friesian bull and produced the grade cow B which showed most of the Holstein-Friesian characteristics except color markings. C was produced by crossing a thoroughbred Holstein-Friesian bull with the grade cow B. This calf would pass as a Holstein-Friesian. It will thus be seen that within only two or three generations the standard of a herd may be raised through grading. (From Babcock & Clausen, after Kildee & McCandlish, Iowa, A. E. S.)

hybridization has progressed so much further in the plant kingdom than it has in the animal kingdom. Until the last few years, the animal breeders abhorred the admission of foreign blood into their breeding pens. Their whole scheme of improvement was based upon the selection of the best material and breeding wholly from it. Their system is still to be complimented, but it must be remembered that other factors are as useful even in animal breeding. In truth, the selection

Fig. 75. A Gujarat zebu cow. Imported from India and considered an unusually superior specimen of the breed. (By permission of the *Journal of Heredity*.)

principle—based largely upon the old theory of inheritance of acquired characteristics—has been carried to such an extreme that even the present-day breeding associations refuse to recognize anything but registered stock whose pedigree must show conclusively that no crossing has been done.

The first material advance over the above system was exemplified in a process known as *grading* (Fig. 74). "In practical animal breeding, grading refers to the method of improving a herd of animals of indifferent blood by the use of pure-bred sires." Practical use is made of grading in the Colorado Rockies where thoroughbred bulls range with scrub cows. There the herds spend the winter in the fertile valleys and in the spring journey up the mountain slopes to timber-line where they feast upon the luxuriant grass until driven down again in the fall by the early snows. All the time while they are on the range, these scrub cows are under the watchful care of both the cowboys and the sturdy thoroughbred bulls. If, perchance, a scrub bull should find his way into this herd,

FIG. 76. An F Zebu-Hereford. The Hereford characteristics appear to be predominant. (By permission of the *Journal of Heredity*.)

he would stand but little chance of mating, for he would soon be subdued and driven away by the great thoroughbred. Thus, year after year, the standards of these western herds are raised both by supplying them with standard bulls and by selling off the poorest cows. This procedure is extremely practical, as an unreasonable investment would be necessary in order to supplant the native cows with thoroughbreds. As an added factor, it would be a hazardous undertaking to subject the latter to such a new and rigorous environment.

If the use of only one standard parent renders such a marked effect upon the offspring, how much more might be expected if the excellent qualities of both parents could be combined in the offspring? In fact, ***cross-breeding*** itself has proved to be of practical value when practiced with a very definite end in view. Thus, in crossing the zebu (Fig. 75) with Hereford cattle, hybrids (Fig. 76) are obtained which seem to have a very high resistance to the foot-and-mouth disease. This cross is very easily made, and the offspring thrive most admirably. On the other hand, certain difficulties are confronted when the bison (***Bison Americanus***, the common American buffalo) is crossed with domestic cows, for the hybrid possesses such a bison-like hump that parturition is very difficult—often causing the death of the mother. Since this cross results in the production of an animal possessing many of the admirable characters of both parents—especially vigor, size and superior coat—the above difficulty should not cause experimentation to cease. By utilizing the hybrid females (the males seem to be sterile) in certain crosses, and by long continued selection, it might be possible to obtain a breed which would prove of much value to American stock growers.

CHAPTER XVII

STERILITY IN HYBRIDS

One Explanaton of Hybrid Sterility—The "mule" as a Type—Noted Cases of Mules Reproducing—Bryant's Reproducing Mule—Contradictory Evidences—Extreme Diversity means Sterility.

The problem of sterility of Hybrids has attracted much attention and many forms have been studied, the causes of most of which seem to be traceable to one general explanation based upon the mechanism of Fertilization. In order to better understand these general principles of hybrid sterility, it seems wise to consider the subject from the standpoint of one particular well known animal—the common mule.

The Mule As a Type of Sterile Hybrid.—A study of the early cells of the testes of this animal shows normal cells with fifty ordinary chromosomes and one sex-determiner. It will be remembered that the horse has only thirty-six, plus the extra chromosome (Refer to Chap. XIV). "This suggests that the number in the ass is about sixty-five, thus making the difference of about twenty-eight chromosomes between the parent and the hybrid." With such a marked difference in the number of chromosomes in the parents, one would expect a catastrophe somewhere along the line of cellular development. Indeed the germ cells do meet with such a disaster while in the process of ripening (Fig. 69, 4 and 5). We have shown in other forms that the maternal and the paternal chromosomes are not directly associated in the somatic and early germ cells, but lie side by side, divide and carry on their other necessary functions independently thru the same cell. This clearly accounts for the real existence of the mule. Should these chromosomes not act independently, the conflict would occur at fertilization and thus the mule would be an impossibility. This independent action further permits the existence of the desirable characteristics of both the horse and the ass in one intermediate individual, but it does not explain the impossibility of an offspring of this hybrid.

It will be shown that when the germ-plasms from two individuals are recombined in the offspring, the offspring exhibits a degree of sterility ranging from complete fertility to complete sterility, and as a general rule, the degree of fertility depends upon the diversity of the parents. Those parents

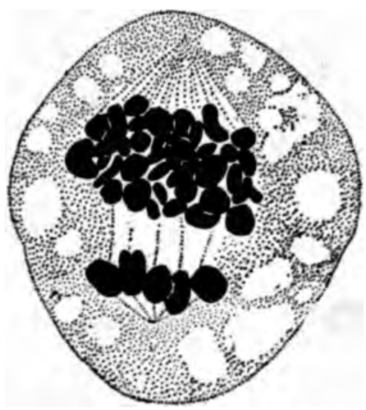

FIG. 77. Abnormal division of the germ cells of the mule is due to the fact that the parents of this animal pass to the offspring a very unequal number of chromosomes. (After Wodsedalek.)

which are only slightly dissimilar produce fertile offspring with but minor variations; those which are dissimilar in more marked respects produce partially sterile hybrids; if still more diverse, completely sterile hybrids and finally, if the forms noted are extremely diverse, no offspring will be produced.

While considering the typical ripening stage of cellular maturation, it was noted that there is a pairing of homologous chromosomes from father and mother. "In the case of the mule, however, because the ovum and the sperm contributed such unequal numbers of chromosomes, there are many without a homologue with which to mate, and even in the case of homologues the physiological incompatibility of the two plasms renders the pairing difficult and incomplete, or prevents it entirely." This disturbance is sufficient to cause a destruction of the ripening germ cells. Wodsedalek (1916) insists that: "Most of the cells disintegrate during

FIG. 78. A Reproducing "mule" (?). The large animal here shown is said to be the offspring of a half-blood Percheron stallion and a black Spanish jennet, and her twin foal (one of which lived only two days) is supposed to have been sired by a gray mammoth jack. The colts would therefore be three-fourths ass and one-fourth horse. (*Journal of Heredity.*)

the prophase, especially during the period of synapsis. Others meet their fate in the metaphase or the early anaphase stage (7, Fig. 69). *The remaining few that survive the anaphase succumb soon after, and no secondary spermatocytes nor spermatids and consequently no spermatozoa are formed and the hybrid remains sterile.*

"There are no authentic cases on record showing fertility ever occurs in this hybrid." (Fig. 77.)

Shortly after Wodsedalek uttered these sweeping conclusions, Lloyd-Jones of the Iowa State College cited (*Journal of Heredity*, Nov., 1916), a number of cases from literature in which female mules and "hinnies" were claimed to be the mothers of colts. The most "authentic" case cited was that of a hinny owned by Mr. J. M. Bryant of Quincy, Indiana. This hinny was reported as having been in foal three times. The first two colts were deformed and died, but the last pregnancy resulted in normal twins (Fig. 78; also see Fig. 79). Another

Fig. 79. A mare mule (?) with a foal by a Percheron stallion. (From Babcock and Clausen, after Lloyd-Jones.)

interesting case is reported by Dr. D. W. Sullivan of Weed, California. This animal is supposed to be out of a standard bred mare and a mammoth jack. She was put to a black Percheron stallion and produced a male "grade mule."

Even tho common observation as well as cytological investigations (Wodsedalek, 1916; also see Goldsmith, 1917), seem to establish the fact that the production of offspring by the common mule is an impossibility, the above cases were, for a while, accepted as scientific facts. The investigations of the author (*Am. Jour. Vet. Med.*, Sept. 1918), however, revealed the fact that these and similar cases should not be accepted until thoroughly investigated. Babcock and Clausen feel quite positive that the California animal reported by Lloyd-Jones is not a mule but rather a common mare which "exhibits mule-like characters." The following résumé of the evidence regarding the non-authenticity of the Indiana case is clipped from the published records of the author.

A visit to Quincy, Indiana, revealed some interesting facts regarding the reproducing mule owned by J. M. Bryant. In the first place, the owner expressed great disappointment when I appeared at his farm without announcing my visit, as he stated that he would like to have had time to "trim the mule up a little." In fact, the first glance at the animal suggested that considerable "trimming" would be necessary before it would resemble the "mule" pictured in various journals and exhibited at the county fairs.

When it was definitely established that the animal under consideration had produced offspring, her parentage was investigated. Lloyd-Jones states that "Some have doubted her breeding until they heard her voice, which resembles more the neigh of the horse." If the voice does resemble that of the horse, which the writer questions, this fact certainly would not establish the parentage. Mr. Bryant claims that this animal is from a "black Spanish jennet by a dark chestnut half-blood Percheron stallion." It developed, however, that this was only a supposed accidental mating. Mr. Bryant states that the jennet (mother of the animal considered) was bred to a jack owned by G. Cradick, Gosport, Indiana, almost fourteen months before the animal under consideration was born (July 20, 1904). The owner claimed that it is impossible for a jennet to carry a colt that length of time, hence the father must have been a three-year-old pony which was in the pasture with the jennet after she was supposed to have been with foal. The owner seems to have stated to Lloyd-Jones that "about nine years ago he bred a dark chestnut half-blood Percheron stallion to a black Spanish jennet" and obtained the above considered animal.

If we assume that the above report is correct, and that the jennet was mated to the jack about fourteen months before a colt was born, the question then arises as to the possibility of a jennet "carrying a colt" almost two months longer than the normal period of gestation, since this is the basis of Mr. Bryant's assumption that the stallion is the father of the above considered animal.

In view of the investigations on deferred fertilization, this case would not be surprising. Summer (Biol. Bul., April, 1916), while breeding certain mice, found that in some the period from the last copulation to the date of birth was more than twice the normal period of gestation (22 days). In his record case No. 5, the last opportunity for copulation was May 17 and the birth of the litter did not occur until July 3—more than twice the period of gestation. In the face of such facts, we do not seem justified in concluding that it would be impossible for a jennet to give birth to a colt almost fourteen months after copulation.

Despite the claims of the owner to the contrary, Mr. Cradick states in writing that "Mr. Bryant never bred any jennet to the jack until July 20, 1906." If we are to accept the breeding records of Mr. Cradick, the date of birth was July, 1907—three years later than Mr. Bryant reported to the writer. However, according to the information given to Lloyd-Jones, the animal was about nine years old in 1916. By counting back it will be noted that the date of birth, according to this statement, was in 1907. Since Mr. Bryant associates July 20 with the birth, indications are that the exact date was July 20, 1907. The period of gestation would therefore be from July 20, 1906 (according to Cradick) to July 20, 1907—exactly twelve months. According to this analysis of the conflicting statements, the animal which has attracted so much attention is a normal jennet—the father being the Gosport jack and the mother the Quincy jennet. The twins (Fig. 78) pictured by Lloyd-Jones and others would, therefore, be common jennet colts. The fact that the period of gestation of this mother is twelve months (July 7, 1914, to July 11, 1915, in the case of the above twins) further suggests that she is a normal jennet, as eleven months is the normal period for the horse.

In the case of either statement of the owner to Lloyd-Jones or to the writer regarding the age of the animal, it seems quite conclusive that the Indiana case of a "Mule That Breeds" is not a hinny mule but a common jennet and thus should be cancelled from the breeding and scientific records.

The same should be concluded of the California case, and others, until *substantial proof* is presented. The principal object of many of these non-authentic reports is to deceive the people and thus to collect an admission fee at the county fairs.

The writer has been informed of a number of other cases of reproducing "mules" but none of them have developed into authentic cases. As a type of these, the following, which was clipped from a large hand bill, will suffice to show the insincerity of the owners.

ONE OF

THE 7 WONDERS

OF THE WORLD

KATE—The Mule That Gave Birth to a Horse Colt

No Fake, Pronounced Genuine by Veterinarians and Scientists

Every Investigation and Test Proves the Genuineness of This
REAL FREAK OF NATURE

NOW ON EXHIBITION
At This Fair Ground

Owned by Sam Edwards and Don Burgess of Caruthersville, Mo.—Exhibition in Charge of Pete Winters

Mr. Q. C. Dobbins, veterinarian, at Bedford, Indiana, in a personal letter to the author reported another interesting case. "This mare mule of fine type aborted a colt in the Bourbon Stock Yards, Louisville, Kentucky. . . . This mule was bought by the Kentucky Agricultural College, for experimental purposes, I presume. These are facts. Miles Standish of Bedford, Indiana, owned her and sold her to the Kentucky school." Certain communications to the parties concerned failed to bring a verification of this report.

Regardless of the controversy over the subject of the sterility of the common mule, it should be evident to the reader that the cause of sterility in the offspring of quite diverse parents may be traced back to the union of the sperm and the egg in fertilization. Such problems can, therefore, be said to be ones of variation through amphimixis and hybridization. Such technical facts form the basis for an explanation of the practical results obtained by the breeder. The value of "technical" explanations is found to be in a definite and tangible method of investigation, as opposed to "trial and error."

CHAPTER XVIII

FUNDAMENTAL PRINCIPLES UNDERLYING THE LAWS OF INHERITANCE

Introduction—Mendel's Experiments—Artificial Fertilization—Mono-hybrids—Heterozygotes—Homozygotes—Laws of Dominance—Principle of Presence and Absence of the Determiner of Characteristics—Law of Segregation—Unit Characters—Di-hybrids—Tri-hybrids.

"We are, at last, on the first round of the ladder leading to an exact knowledge of the phenomena of heredity."

"An exact determination of the laws of heredity will probably work more changes in man's outlook on the world, and in his power over nature, than any other advance in natural knowledge that can be clearly foreseen."

Introduction.—During the middle and latter part of the Nineteenth Century, the entire thinking world was held spellbound by the startling and epoch-making works of Charles Darwin and his few supporters. The publication of the *Origin of Species* (1859) marked the beginning of a period of almost two decades of seething controversy. The introduction of Darwinism was like the promulgation of a new religion, in which converts were won only thru the keenest kind of argumentation.

It is not surprising that a new theory, advanced by a more or less obscure character, should be lost in the midst of these heated controversies. Such was the fate of the records of the now famous experiments with garden peas performed by the Austrian monk, Johann Gregor Mendel. Although his works were scarcely recognized by his former teacher, Karl Nägeli, they are now considered the basis for the improvement of cattle, horses, grains, fruits, and even of the human race. Regardless of the fact that recent investigators have enlarged upon and formulated valuable explanations for the principles set forth by Mendel, they are still considered by both zoölogists and botanists to be "models of genetic investigation." Coulter says, "Mendel's law is the basis of all work in

Fig. 80. Gregor Mendel, 1822-1884. (From Locy, after Bateson.)

genetics and should be understood from its original statement to its somewhat complex development." In view of the great importance attached to the subject of Mendelism, it seems expedient to present a somewhat detailed consideration of its cardinal points.

Mendel and His Experiments.—Gregor Mendel (Fig. 80) was the son of an Austrian peasant. After being educated in Augustinian Foundations, he was ordained as a priest.

"For two or three years he studied Physics and Natural Science in Vienna, and refers to himself as a student of Kollar." He was for some time president of the *Natural History Society of Brünn.* Later in life, he was made abbot of his cloister. While serving as a monk in the monastery of Brünn, a small Austrian village, Mendel seems to have taken particular interest in the cultivation and study of various kinds of plants. Although he studied plants as a pastime, he was not satisfied with the usual casual observations. He delighted especially in raising plants which were pure in their type, and crossing these pedigreed forms with other pure types.

Mendel's principal work was based upon the edible pea. In all probability, he selected the pea as a basis for his experiments because it possessed so many different and distinct characteristics, and because the flower could be easily protected from foreign pollen. This was necessary, as the essential features of his work were to cross two different forms, count the different kinds of offspring, plant the seed from these offspring and study the types from them for a number of generations. Mendel experimented with over twenty varieties of garden peas. Among the characteristics studied, the following are the most important: color of the seed, color of the pod, position of the flower on the stem, length of the stem, and the form of the ripe seed.

After working for about eight years, he presented his data, together with comments, to his former teacher, Karl Nägeli, of the University of Vienna. Although a very noted worker in the field of biology, Nägeli did not seem to recognize the importance of his former student's experiments, and permitted them to sink into oblivion. The only publicity given to them was by Mendel himself, who presented the data, with interpretations, to the members of the *Natural History Society of Brünn.* The paper appeared in the 1865 proceedings of this society (*Verhandlungen naturf. Verein in Brünn. Abhandl. IV, 1865*), under the title of "Experiments in Plant Hybridization." Owing to the fact that the minds of the scientists were absorbed in the startling claims of Darwin, which they considered to be more vital problems, no more was known of Mendel's experiments until 1900.

During these thirty-five years (1865-1900), Darwinism had received so many converts that the storm of controversy had about passed away. Indeed, long before 1900, the best scientists had accepted the once "radical" statements of Darwin as facts, and had turned their minds in pursuit of other phases of knowledge of the subject. However, a large amount of the investigation was influenced by Darwin. This is shown in the epoch-making discoveries of 1900; for, "this year marks the beginning of a new era in the study of inheritance." This year was, indeed, made memorable in the annals of science by the significant works of, particularly, three investigators representing as many nations; namely, Hugo de Vries of Holland, von Tschermak of Austria, and Correns of Germany. It is indeed remarkable that these three men, working independently and representing three different nations, should, in the same year, publish papers dealing with the same phase of heredity! At the same time, De Vries unearthed the old papers of Mendel and found them to contain essentially the same principles as were contained in his own and these other two papers of the new discoverers. These important principles of heredity were therefore called *Mendelism,* although neither of the three workers had profited by the faithful work which Mendel had done over thirty-five years before. Immediately following the publications by the above workers, Bateson in England, and Castle in America, issued monographs dealing with the same subject. So, as out of the sky, the cardinal principles of plant and animal breeding became known to the biologists thruout the civilized world.

Since the Mendelian method of experimentation with the problems of inheritance was rediscovered in 1900, workers in this field have sprung up in every nation where biologists are in the least interested in the problems of evolution. The Mendelian principles were first found to apply to plants, but

Cuenot (1902) and Bateson soon established the fact that they apply to animals as well. Hundreds of amateur workers in the field of plant and animal breeding have taken delight in repeating the elementary experiments of Mendel and more recent workers. This repetition of the experiments of other men would naturally lead even the amateur workers to make crosses of plants or animals which had not been tried before. For example, the author has known high school boys who were attracted by Mendel's experiments to repeat them, using corn instead of peas. The Mendelian method of experimentation has, therefore, become so common that, in many instances, it is difficult to state positively who should be given credit for certain crosses. Several times the method has been so im-

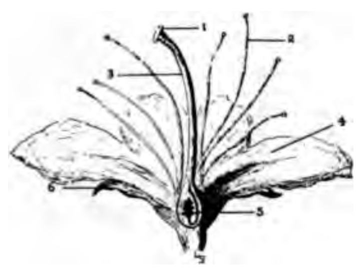

FIG. 81. Showing parts of a flower. 1. Stigma. 2. Stamens. 3. Style. 4. Petals. 5. Ovary. 6. Sepals.

proved by those who repeated the experiments that they deserve more credit than the worker who first attempted it. Altho the experiments considered in the following pages are all classed as "Mendelian experiments," many of them should be credited directly to present-day workers.

Artificial Fertilization.—Before considering the Mendelian experiments, it becomes necessary to explain the method of fertilization in typical plants. Although Mendel's experiments were concerned primarily with garden peas, the work in recent years has assumed a much broader aspect so that it covers a study of a great number of plants with a view to improvement.

In all experiments with plants it is necessary to protect the flower from the pollen of plants which are not desired in the cross. This is somewhat difficult to accomplish in plants such as the edible pea, which is commonly self-fertilized; that is, the pollen of one flower enters the stigmas of the same flower and thus the flower fertilizes itself. It is, therefore, essential to remove the stamens before the anthers begin to shed the ripe pollen. (See parts of a flower, Fig. 81.) After the stamens are removed, small paper bags are tied over the flower (Fig. 82) to prevent indiscriminate fertilization. As pollen might be brought from some other flower by the wind or by

Fig. 82. Paper bags tied over peas showing how to prevent indiscriminate fertilization.

insects, this method of protection must be practiced. When the mutilated flower is ripe, pollen from any flower with which a cross is desired is dusted upon the stigma of the flower from which the stamens have been removed. The pollen may be transferred from the anthers of one flower to the stigma of another by the use of a small camel's hair brush or by simply touching the parts with the tip of the finger. Since, with any species, pollen may be in the air, it is necessary to exercise the greatest precaution to prevent the admission of foreign pollen during the process of the experiment. For example, among the many precautions, it is usually advisable to rinse the fingers and instruments in alcohol before each experiment. After the period of pollination is over, the sacks are removed and the plants are watched and the results recorded. The seeds produced from such a cross are said to be *hybridized*, and the plants produced from these seeds are *hybrids*. Such plants, of which a record of the ancestral characteristics is kept, are *pedigreed*—a term which is also used in animal breeding.

Various methods are employed in the pollination of different plants, but space will be given for a brief consideration of only one of these which was (Ind. Acad. of Sci., 1917) devised by Weatherwax for the pollination of corn. An elongated envelope, open at both ends, reënforced at the bottom by a fold in the paper, and paraffined to make it waterproof, is slipped over the ear before the silks are receptive. Cotton is stuffed in from below to make the envelope tight and still give ventilation. Then the top is folded over and fastened with a paper clip. Pollen is collected in a paper sack which has been slipped over the tassels of the plant with which a cross is desired. In order to pollinate, the clip is removed from the paraffined bag and the pollen is emptied in over the silks. The clip is then replaced over the folded top to prevent the admission of foreign pollen. The whole is removed when ample time has been allowed for complete fertilization.

Before attempting any experiment in Mendelian inheritance, it is necessary that the experimenter be familiar with three facts regarding the plant or animal with which he expects to work. First, *certain distinct and differentiated characteristics must be recognized*. It would be useless to cross two varieties of corn without being able to recognize the characteristics of each variety. The more distinct these characteristics are, the more likely will be the success of the experiments, especially for the beginner. The corn which results from a cross between a white and a red variety could be clearly recognized as red, white, or mixed; and if red and white grains are on the same ear, they can be counted. Second, *the normal breeding habits must be understood.* This applies particularly to plants. The location of the male (pollen) and female (stigma) parts of the plant, and the time and method of fertilization must be known. The experiments would be somewhat different if both peas and corn are to be considered, as the flowers and the methods of fertilization are not the same. Third, *the fact must be fully established that neither of the forms to be crossed is mixed.* That is, *each must breed true to its type.* If white and red corn should be crossed, and were it not known whether or not the red was mixed with some other form, the experiment would be useless. In such cases, both types should be planted separately for at least two years in order to see if the red produces only red and the white only white. After the above facts are understood, even the amateur can proceed successfully with the more simple Mendelian experiments.

Mono-hybrids.—An offspring, produced from parents differing in *only one* characteristic, is called a *mono-hybrid,* this being the simplest type of Mendelian crosses. Since the method of fertilization and the general appearance of corn is familiar to almost everyone, this plant will be of sufficient interest to be used as a type of a simple Mendelian cross. As the fertilization of corn is effected by the shedding of pollen from the tassels (representing the male part of the plant) upon the green silks (attached to the female part), it is a very simple matter to alter or control this normal process. The essential step lies in preventing the pollen from touching the silks until so desired by the experimenter.

A cross which was originally worked out in detail by East and Hayes, the elements of which have been repeated even by novices, is one between the "common" white corn and the "sweet" corn. The former is spoken of as *starchy* to contrast it with the latter, which does not possess the ability to produce mature starch grains. Thus, sweet corn is very wrinkled when mature. This *wrinkled* condition renders it easily distinguishable from the common smooth variety.

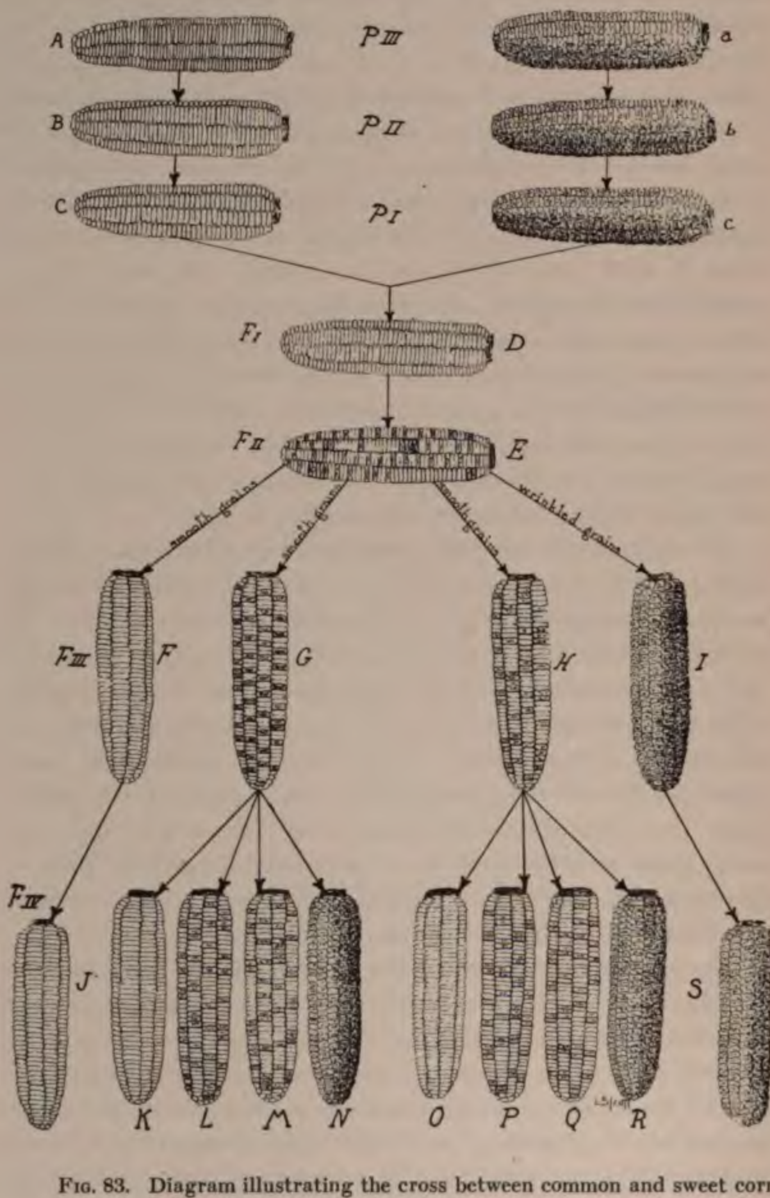

Fig. 83. Diagram illustrating the cross between common and sweet corn.

After testing both the common and the sweet corn for two years to ascertain their purity (A and B, Fig. 83), the progeny (C) are then crossed. That is, the silks of the common corn are protected as suggested above. Pollen is collected from the tassels of the sweet corn and placed in the sack which surrounds and protects the silks of the common smooth variety; or, the reverse cross might be made. From this cross, one might expect ears bearing both common (starchy) and sweet (non-starchy) grains. The facts of the actual experiment, however, do not agree with our assumption; for, the cross between the sweet and common corn (C, Fig. 83) results in only the common starchy grains (D). From the appearance of this corn (D) it seems as tho the sweet corn had no effect, as the ears could not be distinguished from those which would be produced by crossing two races of pure smooth corn. The matter is entirely different, however, when this corn is planted the next year. The plants will bear both common and sweet corn (E, Fig. 83). A count will reveal the fact that the number of starchy grains will be approximately three times the number of sweet grains. That is, suppose that 16,000 grains are counted, theoretically 12,000 would be common smooth starchy ones and 4,000 would be the typical rough sweet corn. The results of the investigations of East and Hayes reveal the fact that these theoretical Mendelian expectations conform very closely to experimental facts. The summary of almost a score of different sets of experiments representing crosses between many races of starchy and sweet corn shows that segregation took place in almost an exact 3:1 ratio. With a total of 31,378 grains, 23,531 were found to be starchy and 7,847 sweet. This gives a ratio of 2.9997:1.0003—indeed, only a very slight deviation from the expected 3:1 ratio.

If these 4,000 sweet grains mentioned above (wrinkled grains in E, Fig. 83) are now planted, they will all produce sweet corn (I). The 12,000 starchy grains (E), however, will not all breed true, but will yield one-third pure starch producing plants (F), and two-thirds mixed starchy and sweet (G and

H). The results, then, of planting the 16,000 grains of the generation shown at E (Fig. 83) would be 4,000 plants possessing pure starchy characteristics (F), 8,000 mixed starchy and sweet (G and H), and 4,000 pure sweet (I). This clearly proves that one-fourth of the 16,000 grains possessed the ability to mature starch grains and thus would be pure starchy; one-half possessed factors for both the starchy and the non-starchy; and one-fourth carried only pure sweet factors. This gives the wonderful 1:2:1 Mendelian ratio which is characteristic of many similar crosses not only with plants but with animals as well. The common starchy ear (F) and the sweet corn (I) and their progeny *will breed true* so long as they are planted alone; the mixed ears (G and H) will produce the same ratio as did E; namely, one-half mixed, one-fourth pure starchy, and one-fourth pure sweet. These last mentioned pure grains will breed true, and the mixed ones will again breed the three kinds. This process will continue *ad infinitum* so long as the experiment is accurately conducted.

Although the ear shown in D (Fig. 83) cannot be distinguished from a pure starchy ear, it was produced by crossing the common and the sweet corn (C), and, in turn, it produced a mixed generation (E). It is therefore a *hybrid* and the process of crossing is known as *hybridization.* In this connection, it should be noted that offspring resulting from the union of individuals that are *hereditarily dissimilar,* with respect to a definite character, are called *heterozygotes,* while those resulting from crossing individuals which are *hereditarily similar* are spoken of as *homozygotes.* Although the ears "D" and "F" (Fig. 83) look alike, the former is heterozygous and the latter homozygous, with respect to the characters under consideration.

Law of Dominance.—Since the hybrid "D" (Fig. 83) was produced from common and sweet corn and will, in turn, produce a mixture of these two varieties, it is evident that it carries some invisible factor which stands for non-starchiness. Therefore, the hybrid "D" contained two factors, but one, the sweet, was suppressed to such an extent that it became invisible. Such characteristics which do not appear when two forms are crossed are said to be *recessive*, and those which appear to the seclusion of others are termed *dominant*. In the case of the corn considered above, starchiness is dominant and non-starchiness is recessive.

Principle of Presence and Absence of the Determiner of Characteristics.—In opposition to the principle of dominance, Correns, Bateson, and others claimed that the recessive character does not exist and that the non-appearance of any character is due to the absence of the determiner which would otherwise produce it. For example, the reason corn is sweet (non-starchy) is not because it has a determiner for sweetness but because the factor for the maturing of starch grains is absent. The reason hornless cattle are hornless is because the factor for the production of horns is absent, rather than that the factor for hornlessness is present. The old term, "recessive," therefore, is to be taken to signify the absence of a factor which produces the dominant character.

According to the presence and absence hypothesis, "a determiner for any character is, or is not, present. When it is present in two parents, then the offspring receive a double, or *duplex* 'dose,' to use Bateson's word, of the determiner. When it is present in one parent only, then the offspring have a single, or *simplex*, 'dose' of the character. When it is present in neither parent, it follows that it will not appear in the offspring. In this case the offspring are said to be *nulliplex* with respect to the character in question. Take the case of tall and dwarf peas; the determiner for tallness, when present, produces tall peas, even if it comes from one parent only, but if this determiner for tallness is absent from both parents, the offspring are nulliplex, that is, the absence of tallness results and only dwarf peas are produced" (Walter).

Such pairs of contrasted characters as the starchiness and non-starchiness in the case of the corn considered above are called *allelomorphs;* that is, factors which occur in the same locus of homologous chromosomes. (See Chapter XX.) Other allelomorphic characters which have been mentioned up to the present are: tallness and dwarfness, roundness and wrinkledness, greenness and yellowness, etc. Allelomorphs, then, are paired characteristics, one of which behaves as a dominant character and the other as a recessive.

Law of Segregation.—In the above experiment it was noted

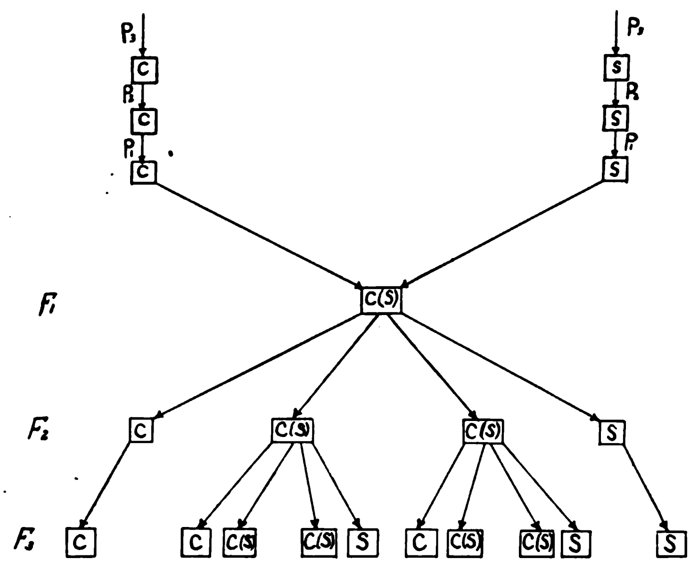

FIG. 84. Diagrammatic representation of the cross between common smooth, starchy corn, C. The dominant character, and sweet, non-starchy corn, S. The recessive character.

that those factors which stood for starchiness and non-starchiness first united in the hybrid (D, Fig. 83), and again separated in the next generations (See E to I). The separation of the two factors which have been united in one individual is the operation of another important law of inheritance; namely, the *Law of Segregation.* This law, as well as the whole scheme of the experiment considered above, might be illustrated further by the graphic representation shown in figure 84, in which *C* stands for common, smooth, starchy corn and *S* for sweet. When such crosses are made, the first generation is spoken of as the first *filial* generation, and, for brevity, is always designated by F_1. The second generation is designated by F_2, the third by F_3, and so on. The parents of the hybrid are spoken of as P_1, the grandparents as P_2, and the great-grandparents as P_3, etc. The Mendelian notation for any hybrid explains the *gametic constitution* of that hybrid. For example, the F_1 generation shown in the accompanying figure (Fig. 84) is represented thus, *C*(*S*). The fact that two letters representing two distinct characteristics are

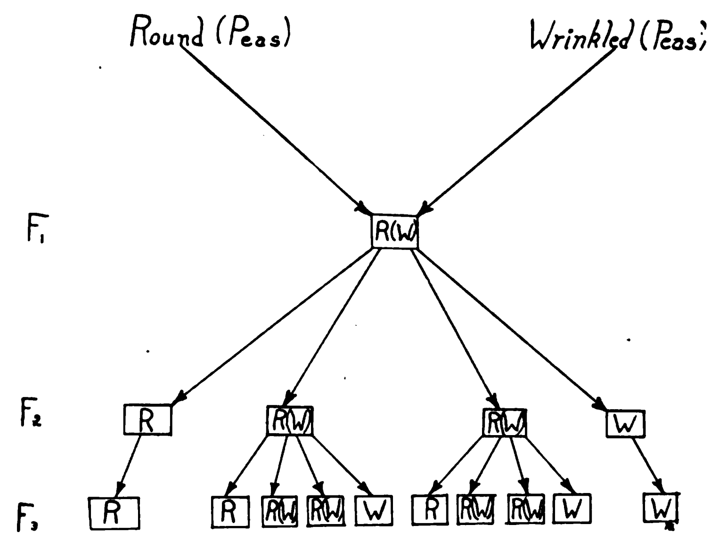

FIG. 85. Unit characters illustrated by crossing round and wrinkled peas. Recessive characters shown in parenthesis.

used implies that the plant under consideration is a hybrid and the parentheses around the *S* suggest that this character (sweetness, non-starchiness) is in the plant but in a latent form and is spoken of as *recessive*. The *C* outside the parentheses explains which of the parents the car resembles, thus representing the *dominant* character. In F_2, these characters *segregate* in definite proportions, the Mendelian ratio, and continue to do so on down the line of filial generations.

Unit Characters.—The principle of dominance and segregation, as well as the entire scheme considered above, is based upon the assumption that every individual is made up of a number of distinct characters which, although they may be located in the same cell, do not blend with each other, so to speak, but behave under the present condition as independent units. For the convenience of illustration, the round and wrinkled peas (referring to the ripe seed) of Mendel will be used to demonstrate the point in hand (Fig. 85). It will be noted from the gametic constitution of the hybrid F_1, R(W), that the character "wrinkled" is recessive since the *W* is placed within the parentheses. Thus, it should be evident that one-fourth of all the peas of the F_2 generation which would result from planting those of the F_1 generation would be pure round, one-half would be hybrids, and one-fourth would be pure wrinkled. The same 1:2:1 ratio may be obtained by simple algebraic multiplication of the factors involved.

$$\begin{array}{l} R + W \\ R + W \\ \hline RR + RW \\ \qquad\;\; RW + WW \\ \hline RR + 2RW + WW \end{array}$$

This problem suggests that a pure pedigreed round pea should be represented by *RR* rather than by *R*, and that a pure wrinkled pea should be represented by *WW*. This double unit constitution of the individual will be understood from an explanation of the accompanying chart (Fig. 86), which shows how the factors in the germ cells behave as units when certain crosses are made.

P_3, P_2, and P_1 represent two generations of breeding to

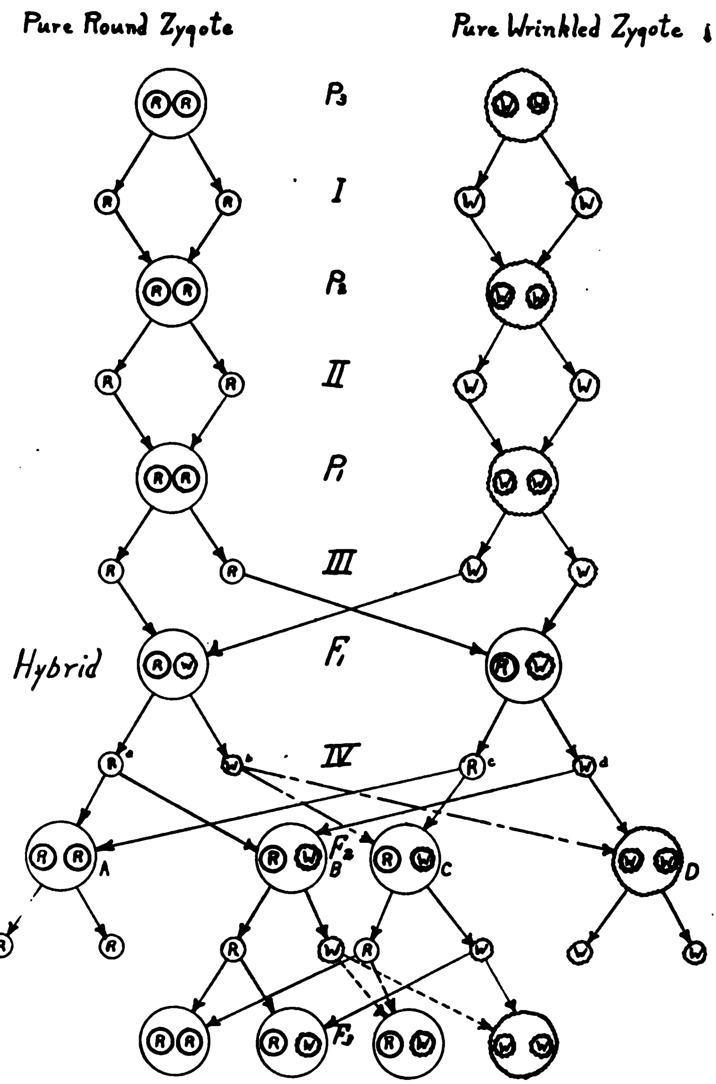

FIG. 86. Diagram illustrating behavior of gametes in the cross between round and wrinkled peas.

test the purity of the parent peas which are to be crossed. Since the parents result from a union of male and female sex cells (in their reduced form), they are called *zygotes* (Gr. yoked). And since the peas (zygotes) which are represented at the top of the figure (P_3, P_2, and P_1) breed true to type, they are said to possess a *double dose* of roundness or wrinkledness, as the case may be. The round peas are represented by large circles and their germ cells are represented by small circles inside the large ones; the wrinkled peas and their germ cells are represented by large and small irregular outlines. A glance will show that a pure pea will contain germ cells with outlines similar to the pea itself. The zygotes produce sperms and eggs in their reduced form (I, Fig. 86) which are spoken of as gametes (Gr. husband or wife; from Gr. to marry). If there is no cross between varieties or species, similar male and female gametes (I, Fig. 86) unite to produce a new zygote, P_2. The same process is carried out for P_1. However, if a male gamete (Right of III) from a pure wrinkled parent zygote (Right of P_1) unites with a female gamete (Left of III) from a pure round parent zygote (Left of P_1), a hybrid (F_1) containing factors which stand for both round and wrinkled germ cells will be produced. As the illustration shows, all hybrids produced by such a cross will be round but, of course, will contain "wrinkled" germ cells. Exactly similar results would be obtained were an opposite cross made; that is, if a female gamete (Right of III) from a wrinkled pea (Right of P_1) unites with a male gamete (Left of III) from a round pea (Left of P_1), a round pea (Right of F) containing a germ cell from the wrinkled pea would be produced. The illustration shows that every pea (F_1) produced by the above cross forms two types of gametes (mature sperms and eggs), one carrying the factor for wrinkledness and the other the factor for roundness. Furthermore, both male and female gametes of each type are formed. If the "round" gamete "c" (Right of IV) should, perchance, meet the "round" gamete "a" (Left of IV), the pure "round" zygote A (Left of F_2) would be formed. On the other hand, if this same "round" gamete "c" (Right of IV) should meet the "wrinkled" gamete "b" (Left of IV), a hybrid zygote C (Right of F_2) containing both "round" and "wrinkled" germ cells would be produced. In like manner, if the "wrinkled" gamete "d" (Right of IV) and the "round" gamete "a" (Left of IV) would give hybrid B (Left of F_2) while this same "wrinkled" gamete "D" would produce, when united with "B" (Left of IV) a zygote carrying a double dose of wrinkledness—thus a pure wrinkled pea.

It is noted, therefore, that, when explained upon the basis of germ cells, one-fourth pure round, one-half hybrids, and one-fourth pure wrinkled is the result—the usual 1:2:1 ratio. The pure round and pure wrinkled peas as shown at the top of the figure again crop out when the germ cells of the hybrids (B and C, F_2 generation) segregate to form the 1:2:1 ratio of pure bred and hybrid peas. This process of segregation in the production of pure lines and hybrids will continue so long as the experiment is kept up. Throughout the above consideration, the characters of roundness and wrinkledness behaved as units. Regardless of the number of times they unite to form zygotes, they always segregate according to a *definite law* which applies to all unit characters. It must not be assumed, however, that every character behaves as unity under all conditions, as was the conception in the earlier days of Mendelism before the trend of thought was shifted to a consideration of the factor. Although the unit character concept is still known to accord with the results of the experimental breeder, especially when considered in connection with certain definite contrasts, it will be shown in the following chapter that such "unit" characters may, under other conditions, behave as compound characters. The discovery of this fact did not render useless, as is sometimes supposed, the working hypotheses of the earlier Mendelians, but rather it simply represents one step further into the field of advanced genetics.

The question often arises as to how a hybrid possessing latent (recessive) characteristics can be told from a pure line.

For example, how is it possible to tell a pure round pea (RR) from an RW when both appear exactly alike? The only satisfactory answer that can be given is: "Plant them and see." In like manner, it is impossible to determine which of any two contrasted characters is dominant and which is recessive until a cross is made.

Another very simple and general method of determining the result of crossing forms differing in one character is presented in the following chart (Fig. 87) representing the crosses

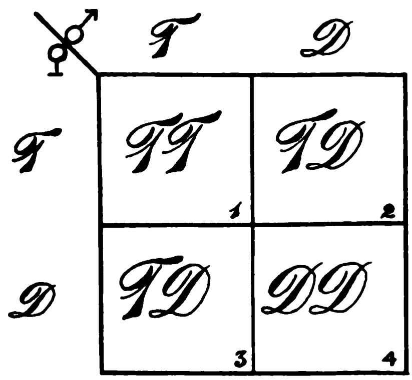

Fig. 87. Diagram showing genetic constitution of the offspring resulting from a cross between tall and dwarf peas.

between hybrid tall and dwarf peas. The letters at the top of the figure represent the two types of sperms which are formed, while those at the side indicate that some eggs will carry the characteristic for tallness (T) and others for dwarfness (D). The sperm T meets the egg T and forms the zygote TT which, of course, will be a tall pea, since it has a double dose of tallness (square 1); the sperm D meets the egg T and forms the hybrid TD, giving a tall pea, since dwarfness is recessive (square 2). The sperm T meets the egg D and forms another tall hybrid TD (square 3); the sperm D meets the egg D to produce a pea with a double dose of dwarfness, DD (square 4). Since TT and DD represent pure lines, DT and TD, hybrids, another clear demonstration of the Mendelian 1:2:1 monohybrid ratio is given.

All the F_1 generation from the cross between polled and horned cattle appear to be polled; but, upon further breeding, the F_2 generation exhibits the characteristic 1:2:1 ratio. The same is true when pure bred trotting and pacing horses are crossed. In the F_1 generation the trotting characteristic is dominant, but in the F_2 generation both characteristics appear in the offspring in the Mendelian ratio. How many present-day practical farmers would consider a pacing horse thoroughbred if both of its parents were trotters and one of its grandparents was a trotter—*only one grandparent* being a pacer? The fact of the case is, however, that such an animal is as much a thoroughbred as if he were the last of a long line of thoroughbreds which were *selected* from generation to generation. Our knowledge of the Mendelian behavior of such individuals resulting from hybrid crosses warrants us in asserting that such a pacer would breed true, and, therefore, would be a thoroughbred. In like manner, thoroughbred horned cattle may be obtained even tho their immediate ancestors were polled. When the facts of Mendelism become well known, perhaps our whole system of pedigree writing will be revolutionized.

Kezer and Boyack (Colo. Ag. College, Bull. 249) have recently reported some interesting results in Mendelian inheritance which were obtained by crossing certain grains, notably wheat and barley. Crosses between Harvest King wheat (red chaff) and Fultz Mediterranean wheat (white chaff) resulted in an F_1 generation in which all the progeny possessed red chaff. Evidently, in this cross, the red chaff was dominant over the white. When red and smooth chaff (Harvest King) was crossd with white and velvet (Fultz Mediterranean), the offspring in the F_1 generation all showed red and velvet characteristics. In this case *two* sets of characteristics are concerned. The F_2 generation of such a cross will not segregate in the 1:2:1 ratio, but will produce a different ratio in accordance with the di-hybrid principles considered below.

Di-hybrids.—Altho the mono-hybrid condition is the simplest type of Mendelian inheritance, it must be remembered that every plant and animal is made up of many sets of contrasted characters (allelomorphs). The greater the number of allelomorphs considered, the more complex becomes the problem. When two such pairs of contrasted characters are involved in a hybrid, the term *di-hybrid* is applicable. Altho the two pairs of factors are embodied in the same cell, they segregate independently of each other and otherwise behave as mono-hybrids. For example, Mendel and others have found

♀ \ ♂	YR	GR	YW	GW
YR	YR YR 1	YR GR 2	YR YW 3	YR GW 4
GR	GR YR 5	GR GR 6	GR YW 7	GR GW 8
YW	YW YR 9	YW GR 10	YW YW 11	YW GW 12
GW	GW YR 13	GW GR 14	GW YW 15	GW GW 16

Fig. 88. Diagram illustrating di-hybrids. Cross between yellow-round, YR, and green-wrinkled, GW, peas, the green and wrinkled characters being recessive.

that when a yellow-round (YR) pea and a green-wrinkled (GW) pea are crossed that a yellow-round hybrid is produced. Since it was known that the green-wrinkled characteristics must have been passed on to the offspring, the yellow-round characters must have been dominant, giving YR (GW) as the genetic constitution of the hybrid of such a cross. This situation may be clearly visualized by a study of the accompanying checkerboard scheme which was suggested by Conklin (Fig. 88). Four types of germ cells may be formed from the above hybrid. These may be ascertained by the following algebraic multiplication:

$$\begin{array}{l} Y + G \\ R + W \\ \hline YR + GR + YW + GW \end{array}$$

In other words, when the germ cells mature there will be four types of sperms and four types of eggs formed; namely, yellow-round, green-round, yellow-wrinkled, and green-wrinkled. In turn, when these gametes reunite during fertilization, the sixteen zygotes indicated on the checkerboard will be formed. The pea represented by the first square (YR YR) will be yellow-round since it receives a double dose of both yellowness and roundness; the second will be yellow-round as it has a double dose of R, and Y is dominant over G. For these and similar reasons, squares 1, 2, 3, 4, 5, 7, 9, 10 and 13 represent yellow-round peas; squares 6, 8, and 14 green-round; squares 11, 12, and 15 yellow-wrinkled; and square 16 green-wrinkled. Thus, in the case of di-hybrids, the individuals of the F_2 generation may be numerically represented by the following relative numbers: 9 YR, 3 YW, 3 GR, and 1 GW. This, 9:3:3:1, is the well-known di-hybrid ratio.

By a similar method of analysis, the offspring of tri-hybrids (plants or animals possessing three sets of contrasted characters) will be found to appear in the following ratio: 27:9:9:9:3:3:3:1. When four sets of characters are involved there will be 256 possible types of offspring, $(3 + 1)^4$. When it is realized that every higher plant and animal is made up of a large number of characters, it is evident that the possible kinds of offspring are very great. In case only a dozen sets of characters are involved, the possible types of progeny will reach the enormous number of $(3 + 1)^{12}$ or 16,697,216. Altho such increasing possibilities render it impractical, from the standpoint of breeding, to deal with more than one or two characters at a time, the advantages lie in the great choice of individuals which differ in salient features and which conform to the most variant desires of man.

CHAPTER XIX

FACTOR HYPOTHESIS

Character vs. Determiner—Determiner vs. Chemical Element—Meaning of Factor—Complementary Factor—Reversion—Di-hybrid Ratio in Complementary Factors—Inhibitory and Modifying Factors.

Thruout the foregoing chapter single letters were used to represent single characteristics—indicating that every character is represented in the germ cell by a distinct determiner. According to this conception, the determiners in the germ cells would be numbered by impossible thousands, since every individual possesses countless characteristics. Although we do not consider this situation to be the case, we are forced to use the old notation, as our knowledge regarding the "make-up" of inheritance has not yet advanced sufficiently far to enable us to use other methods. Suppose, for the sake of comparison, that the chemist should follow the method of the biologists and attempt to represent each of the thousands of compounds by separate symbol. This arrangement would be very impractical, for the various compounds are made up of a relatively small number of elements. Is it not possible, as has been suggested by a number of biologists, that there are a comparatively small number of determiners, which by their different combinations make up the various characteristics in somewhat the same sense as the 86 or more elements make up the chemical compounds?

As a proof that this conception actually has a substantial working basis, it should be noted that a number of instances have been cited, in which two or more factors are necessary in the production of certain characters, a situation analogous to the combination of two or more elements to produce a certain chemical compound. It is, therefore, no longer to be considered that there is always a single "something" which acts as a *determiner*, but rather that various combinations of "somethings" called *factors*, when acting under certain conditions of combination, produce specific characteristics such as hair, skin, or eye color, a certain disposition, etc. This consideration of "factors" rather than "determiners" is the basis for the *factorial hypothesis*, which *is one of the first steps toward the light in the advance of present-day genetics*. It must not be understood that the idea of factors is intended *entirely* to supplant the determiner concept. In truth, in the simple cases of Mendelian inheritance in which a character is determined by only one factor, the terms *determiner* and *factor* are synonymous. In such cases the term *determiner* should be retained.

The most common examples wherein more than one factor is involved in the production of a single characteristic, are found in color development in many plants and animals (*Complementary factors*). A few of these puzzling cases might be mentioned. By crossing red and white corn, East found that red was dominant in the F_1 generation. According to the principle of segregation, set forth in the preceding chapter, one would expect the second year's planting of these red hybrids to yield the 3:1 ratio—three red to one white. Instead of this ratio appearing, the experimenter found 9 red grains to every 7 that were white. This same unusual 9:7 ratio has been found to result from the mating of certain colored rabbits and mice, as well as guinea-pigs.

As a simple explanation of the interaction of the complementary factors to produce this 9:7 ratio, Bateson's experiments with white peas will be considered. The two varieties which were crossed were indistinguishable except in the shape of the pollen grains which, indeed, should have no direct bearing on the color of the flower. Each of these varieties was found to breed true to the white color, and, thus, one would expect the progeny which resulted from a cross between the two to be "pure" white. However, such was not the case; for, instead, all the hybrids were *purple*. Since these hybrids resembled the wild Sicilian pea, the phenomenon was thought, for a time, to be a simple case of so-called *reversion* to a primitive ancestral type. Future plantings, however, revealed the fact that the "reversion" was nothing more than a strict conformity to a newly discovered phase of the Mendelian principles of inheritance. These purple hybrids produced colored and white flowers in the proportion of 9:7. The following interesting conclusions were developed from these experiments:

1. Two factors are involved in the production of color.
2. Each of the original parents possessed one of these factors.
3. A plant will remain "pure" white so long as it possesses only one of these factors.
4. The union of these two complementary factors will produce a colored hybrid.

Di-hybrid Ratio in Complementary Factors.—Since two factors are involved in the production of color, the explanation for such unusual cases as the peas considered above can be based upon the principles of di-hybrids considered in Chapter XVIII. In this case, in order to construct a diagrammatic representation, capital P might represent the *pigment* factor, and small p the *absence* of this factor; capital D might stand for the *color developer*, and small d for the *absence* of this factor. The four types of sperms and ova would, thus, be derived in the same manner by algebraic multiplication.

$$\begin{array}{l} D + d \\ P + p \\ \hline PD + Pd + pD + pd \end{array}$$

The genetic constitution of the types of individuals produced by the unions of these sperms and ova are developed as represented in Fig. 89. Since both the Capital P and the capital D must be present before a colored flower is produced, it will be noted that the squares numbered 6, 8, 11, 12, 14, 15, and 16 present a genetic constitution which will produce peas with white flowers, while all others will be colored. The ratio. therefore, is 9:7.

It will be noted that if only the above two factors are in-

♀ \ ♂	PD ↓	Pd ↓	pD ↓	pd ↓
PD →	PD 1 PD colored	Pd 2 PD colored	pD 3 PD colored	pd 4 PD colored
Pd →	PD 5 Pd colored	Pd 6 Pd white	pD 7 Pd colored	pd 8 Pd white
pD →	PD 9 pD colored	Pd 10 pD colored	pD 11 pD white	pd 12 pD white
pd →	PD 13 pd colored	Pd 14 pd white	pD 15 pd white	pd 16 pd white

FIG. 89. Diagram illustrating the 9:7 di-hybrid ratio in complementary factors, using Bateson's experiments with white peas as a basis. (See text.)

volved, the flower is not colored even though it might possess a double dose of either the pigment factor or the colored developer. Even though the pea represented by square 6 possesses a double dose of the pigment factor, P, it is necessary for the developer, D, to be present before a color appears. Conversely, the double dose of developer, D, in square 11 can produce no effect so long as there is no pigment to be developed. It should be mentioned, however, that in many cases, other factors than those which enter into the above combinations are present, making the problem much more complex. Indeed, in this very illustration the color form is of six different types. In the production of coat color in the rabbits, Castle finds that eight different factors enter into the combinations.

The development of further knowledge concerning the laws of inheritance is revealing many other factors which play vital parts in the formation of various characteristics of the individuals. East and others have found that many plants and animals possess *inhibitory factors* which prevent the development of certain other factors. Such a factor would thus have an opposite effect from the "developer" considered above. Other factors act as *modifiers* (supplementary factors). That is, the association of a supplementary factor with some other dissimilar factor causes that factor to express itself differently than it would otherwise.

CHAPTER XX

APPARENT EXCEPTIONS TO THE LAWS OF INHERITANCE

The Chromosome Hypothesis—Experiments of Thomas Hunt Morgan and his Co-workers on the Fruit Fly—Four Groups of Hereditary Characters in *Drosophila*—Loci of Genes in Chromosomes—Linkage of Factors—Crossing Over—Interference—Deficiency and Duplication—Non-disjunction.

"That the fundamental aspects of heredity should have turned out to be so extraordinarily simple supports us in the hope that nature, may, after all, be entirely approachable."

—*Thomas Hunt Morgan.*

No specific statement has been made regarding the direct relation which exists between the chromosomes and the individual characteristics. However, it has been suggested that the whole scheme of inheritance is based upon the chromosome hypothesis. The more the facts of heredity become known, the more does this seem to be the true situation. Mendelism, as such, is entirely explicable on the basis of chromosome behavior. All the apparently exceptional cases which have been studied thru to a solution bear out the fact that the chromosomes do behave in the expected manner. This alone would seem to indicate that the chromosome mechanism is the fundamental element in hereditary transmissions.

The most conclusive demonstration of the above fact has been presented by Thomas Hunt Morgan of Columbia University, his co-workers, and students. In their work on the vinegar fly, *Drosophila*, they found that the hereditary characters of this insect fall into four great *linked* groups corresponding to the four pairs of chromosomes. Even the size relation between these hereditary groups and their corresponding chromosomes holds good; there are three groups of characters corresponding to the three large pairs of chromosomes and one small group of characters corresponding to the one small pair of chromosomes (Fig. 90).

I	II	III	IV
Yellow, Spot	Streak	Sepia	Bent
White, Cherry, Eosin	Dachs	Pink, Peach	Eyeless
Abnormal	Black	Kidney	
Bifid	Jaunty	Ebony, Sooty	
Lethal II	Purple	Beaded	
Lethal sb	Vestigial	Rough	
Club	Curved	Rose	
Lethal IIIa	Arc	Scarlet	
Lethal sa	Speck		
Lethal III	Morula		
Vermilion			
Miniature			
Furrowed			
Sable			
Rudimentary			
Bar			
Fused			
Lethal sc			

The actual numbers of characters as recorded in these four groups bear a very close mathematical relationship to the actual sizes of the chromosomes in question. This work has been so extended that it is now firmly established that the genes (factors) which are responsible for corresponding characters are not only located in definite chromosomes but at definite points in the chromosomes. Inductive and deductive reasoning both lend support to the contention that the genes have linear loci in the chromosomes. The application of this fact will be made clear when *crossing over* is taken up for discussion.

In the chromosomes of the *Drosophila*, the respective groups of characters are inclined to remain together in passing from one generation to another. Furthermore, the members of each group are transmitted independently of those of other groups. This is one of the most extreme variations of the earlier Mendelian principles and one which, indeed, has played a great part in causing "Mendelism" to be greatly extended. This type of inheritance in which factors tend to pass along together is spoken of as *linkage*. This term applies to certain cases

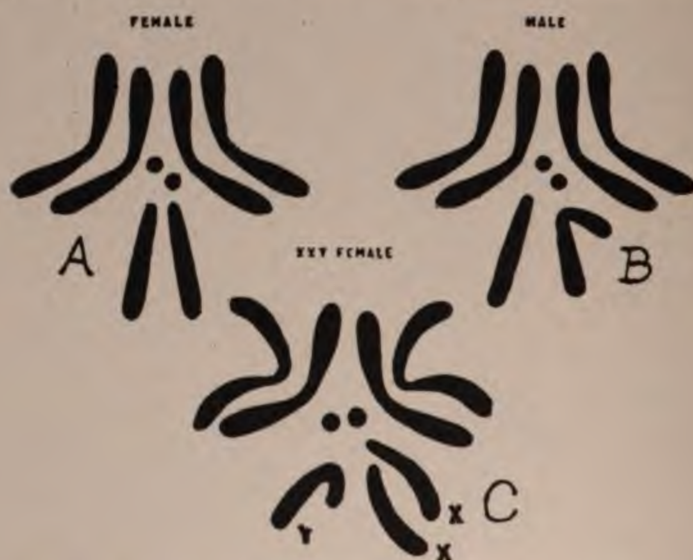

FIG. 90. Chromosomes of Drosophila. A. Female, B. Male, showing the four pairs of chromosomes with which the four groups of characters correspond. Note that the number of characters in each group correspond with the comparative size of the pairs of chromosomes. C. Chromosomes of a female, in which, thru non-disinjunction, a "male" chromosome has been added. (From Morgan, *et al.*)

wherein the characters in question tend to keep together instead of segregating in accordance with the usual Mendelian principles.

There are two extremes between which all degrees of linkage may be found. On the one hand, the characters in question tend to hold together absolutely, while on the other extreme, linkage may be of very unusual occurrence. Many cases of linkage have been described in which the given characters show only a slight tendency to stick together. In this case, the usual assortative mingling of characters is the rule and linkage the rare exception. For a given set of characters, however, linkage has a very definite mathematical ratio. This last holds true whatever may be the degree of linkage involved. A well known case of linkage is considered in Chapter XXVI, under the title of Criss Cross Inheritance. It will be shown there that the factor for color-blindness is located in the sex-chromosome and is consequently ***sex-linked.***

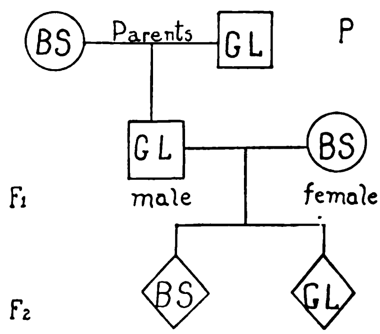

FIG. 91. Diagram Illustrating Linkage. (See text.)

Complete linkage of characters might be illustrated by the following (Fig. 91). In crossing a fly, *Drosophila*, with a black body color and with short (vestigial) wings with one of wild-type, or gray body color and long wings, the offspring (F_1 generation) will all possess the normal characteristics of the species; *e.g.*, gray body color and long wings. Of course this result will take place only if the parents are homozygous with respect to their particular characters, that is, if the allelomorphs are the same in each chromosome pair. If now, one of the *males* of the F_1 generation obtained as outlined above should be crossed with a black vestigial-winged female, the F_2 offspring would exhibit two different sets of characters identical with those shown by the parents in the F_1 generation. These offspring would appear in the definite ratio of 1:1. Here it will be seen that characters which went in together with the original cross have come out together. In other words, they have remained linked. Another interesting exception to the earlier Mendelian concepts is a peculiar phenomenon called *crossing over.* In this case allelomorphic genes, or groups of genes, exchange places in their respective chromosomes. This "hereditary" peculiarity has also been worked out most extensively in the fruit fly, but much work is now being done with other forms in order that the principles involved may be

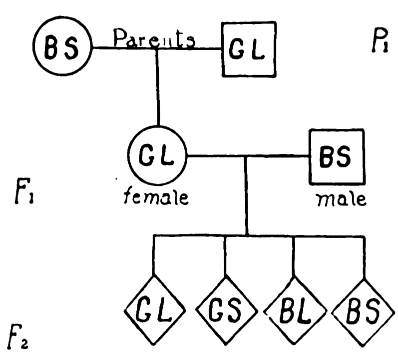

FIG. 92. Diagram Illustrating crossing-over. (See text.)

more firmly established and their universal application demonstrated. (See works of White, 17, Emerson, and others.)

In order that the reader may gain an idea of the manner in which *crossing over* manifests itself, the following illustration of this phenomenon is presented. We will presume that an F_1 generation has been produced by the crossing of the black vestigial-winged fly with a normal gray body-colored fly with long wings. This F_1 generation will all possess gray body-color and long wings. So far, it will be seen that the experiment parallels the one given under linkage (Fig. 91). However, in this case, instead of using a *male* for the next cross, a *female* will be used (Fig. 92). If this wild-type (gray) female of the F_1 generation is crossed with the black vestigial-winged male there are four kinds of offspring produced instead of two as appeared in the other experiment. In this case, the two original kinds represented in the P_1 (Fig. 92) generation reappeared together with two new combinations of the same characters; viz., wild-type color and vestigial wings, and black body color and long wings. These last two types are known as the *cross over* types. In order for them to be produced, there must be an exchange of genes of the allelomorphs affected; otherwise, the characters would remain truly linked and thus

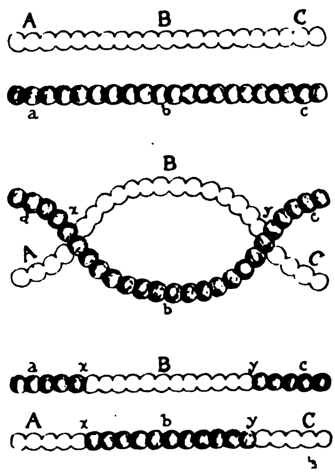

FIG. 93. Diagram illustrating how crossing over may occur. In this case "double-crossing over" is illustrated since the two chromatin fibers cross twice, at x and y.

this variation known as the crossing over would not take place. In the experiment given first under linkage, a *male* was used for the cross to produce F_2 generation; in the one just given, a female was used. The significance of this lies in the fact that there is no crossing over in the male of this species, while such does take place in the chromosomes of the female. This mechanism of crossing over, from the standpoint of the chromosomes themselves, is the next phase of the subject which will be discussed.

An elementary conception of how crossing over might occur may be gained from a consideration of the accompanying diagram (Fig. 93). For a better understanding of this figure, the reader should refer to the discussion of the maturation of germ cells (Fig. 69). It will be remembered that during this process the chromatin fibers are found to be in a tangled condition—sometimes one thread will be twisted about another. Certain breeding experiments indicate that these chromatin fibers actually exchange parts when in this entangled condition. Consider the two chromosomes A B C and a b c (Fig. 93). Suppose them to be twisted about each other as shown in the middle drawing of the figure. If each of the chromosomes in question should break at the points x and y, where they come into contact with each other, and if the pieces should then reunite, the results would be as indicated. In this case, instead of the two chromosomes being made up of normal parts A B C and a b c, they would be made up of parts A b C and a B c. It will be noted that if this factor (gene) or a group of linked factors is located in the middle part of the chromosome, and the allelomorphic factor, or group of factors, in the one with which it pairs, there will be an exchange or a *crossing over*. That is to say, the chromosome which once possessed the genes or groups of genes A B C now has the new set A b C.

In the above outlined case of crossing over, it will be noted that the points A C and a c remain unchanged throughout the process. If these two allelomorphic factors or groups of factors were the only ones being considered in the experiment, crossing over would not be detected. In order for crossing over to be detected, enough factors must be selected to cover all possible cases. It is herein that is presented one of the most convincing proofs that the genes have a *linear* arrangement in the chromosomes. For crossing over to take the place as it does in definite mathematical relations implies that the genes must have definite loci, otherwise no amount of intelligent experimenting could reduce the data to anything more than a hopeless jumble of unrelated facts. A detailed study of cross-overs reveals the fact that they do "give numerical results in constancy." In fact, it is questionable if any fundamental principle of heredity will prove more valuable in the solution of the many puzzling problems of inheritance than will the theory of crossing over and the many other principles which are related to it.

An interesting phenomenon associated with crossing over and one which has added much support to the theory that the factors are definitely arranged in a linear series in the chromosomes is that of "*interference.*" An explanation of interference is based upon the fact mentioned above, that crossing over is caused by the twisting of the chromatin fibers during certain maturation stages of the germ cells. When they twist so as to touch and "cross over" at certain points, the cross at this particular point *interferes* with other crossings which might have otherwise occurred on either side of such points. For example, it should be clear that the regions on either side of x and y (Fig. 93) are less likely to be affected by further crossing over than if the distance between the two points had been greater. The relation which this principle bears to crossing over and its application to heredity are quite significant.

It is surprising to note that certain crosses establish the fact that at times the chromosomes may actually lose pieces and thus genes or groups of genes may be dropped out entirely. If, on the other hand, pieces may be added to the chromosome, the individual will possess more factors than it would otherwise have possessed. The dropping out of pieces from a normal chromosome has been termed "*deficiency,*" and the addition of factors "*duplication.*"

The last unusual behavior of the chromosomes, as revealed in the *Drosophila,* to be mentioned in this connection is "*non-disjunction.*" This term refers to a peculiar mishap in the chromosome mechanism which occurs in the reduction division (Fig. 69) in which homologous chromosomes fail to disjoin, but pass on to the same gamete. The general principle herein involved will be seen by considering the way in which the gametes are shown in Fig. 94. Under normal conditions, the two gametes from the female (A) would be alike, *x* and *x*. But in rare cases, the two *x's* may fail to separate, or *disjoin*, in the reduction division of the maturation of the germ cells and thus one gamete would contain two *x's* and the other none. When such eggs (gametes) are fertilized by normal sperms, interesting offspring are produced. If the *x* sperm (Fig. 94) meets the *xx* egg, a *xxx* (a), rather than a normal *xx* individual will be produced. If the *x* sperm meets the egg with no *x*, an *x* offspring (c) is produced. If the *y* sperm meets

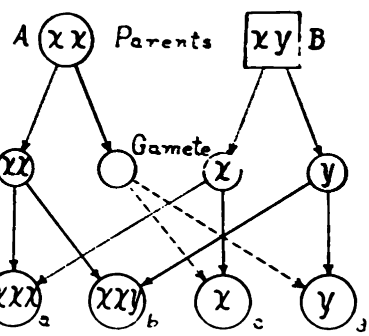

FIG. 94. Diagram illustrating the behavior of gametes in case of non-disjunction.

these two types of eggs, *xxy* (b) and *y* (d) individuals are formed. These offspring would, of course, possess characteristics quite different from what might be expected under normal conditions. In fact, such marked exceptions were first noted during experimentation with *Drosophila* and they seemed at first to be weighty evidence against the chromosome hypothesis. However, this seemingly contradictory evidence was the strongest proof that characters do follow definite chromosomes; for, when the cells of these exceptional individuals that possessed the additional characteristics were examined under the microscope, *they were found to contain an extra chromosome which corresponded exactly with what was expected.*

In figure 90, may be seen the chromosome group of a normal female, together with the chromosomes C of one of these exceptional females. It will be noted that thru *non-disjunction* the *y* which, in this particular case, should be in the male cells has passed into the female. The above and many other principles which have been worked out by the Morgan schools, involve too many technicalities to be presented here in detail. A reference is made to them in order that those interested may gain a knowledge, altho superficial, of the basic facts. Those who are interested in going deeper into the facts which underlie the future study of heredity have ample opportunity to do so. The many experts who are at work in this field are constantly publishing the results of their researches. The list is growing by leaps and bounds. At the present time it contains the contributions of many of the greatest workers in the field.


THE CATLIN MARK
A
B
C
D
E
F
G

The Catlin Mark

Plate I. The accompanying plate presents an unusual type of human inheritance. The central character under consideration is indicated by a white cross in the family chart, Generation IV. The skiographs (C and E) at the top of the plate show clearly that this lady has a large opening in each of the parietal bones. The white arrows between C and D are intended to show that she inherited this remarkable abnormality from her father whose photograph is shown at D. The family chart at the bottom of the plate shows the striking fact that the "Catlin Mark" is inherited thru at least five generations. The Eugenicists are concerned with such cases only as far as it establishes the fact that family traits are inherited. The members of the Catlin family are no more inconvenienced, or need be no more humiliated by this unusual condition than by a pug nose, a freckled face, or "cat eyes." It is only thru the admirable coöperation of such families as this that the science of Eugenics can be advanced and thus placed upon a more practical basis. In many cases there comes a feeling of resentment when the family history is to be investigated, the members claiming that "it is nobody's business what kind of a family they have." (From a display by the author.)

CHAPTER XXI

HUMAN INHERITANCE

Mendelism, a Practical Science—Berkeley Policemen see the Value in the Study of Human Inheritance—Absurd vs. Reasonable.

"Genetics *is the science which seeks to account for the resemblances and the differences which are exhibited among organisms related by descent."*

"Eugenics *is the study of agencies under social control that may improve or impair the racial qualities of future generations, ether physically or mentally."*

"An exact determination of the Laws of Heredity *will probably work more change in man's outlook on the world, and in his power over nature, than any other advance in natural knowledge that can be clearly foreseen.*

"To Gain This Knowledge *is the object of the science of genetics, which proceeds in practice, largely by means of plant breeding and animal breeding for the reason that heredity is less complicated in these organisms than in man, and its operation can be more easily made out. The knowledge so gained finds its application in methods for the improvement of cultivated plants and domesticated animals and, most important of all, in the improvement of the human race, through the science of eugenics."*

The Value of Mendelism.—For many years the Mendelian Theory was considered a mass of impractical, technical assumptions. After the facts of the experiments were established, it was still thought to be impossible to make a direct application of the principles involved. However, this view is rapidly changing, and Mendelism is not only coming into practical use, but it is serving as an incentive for a study of other practical principles of heredity.

Mendelian inheritance has been worked out in such detail, with plants and animals, that now the problems confronted are comparatively simple. With man, however, progress has been quite slow and difficult. It is impossible to test for a "pure line," if there be any such thing, as experimental breeding is entirely out of the question. We are forced to rely on statistics compiled by tracing the histories of families. This method of procedure is extremely slow, as man is a very slow breeder and produces so few offspring. If the rate of production be thirty years for each generation, there have been only about fourteen generations since America was discovered.

When the Mendelian laws were rediscovered, it was recognized that there would be great advancement could we realize that they apply to man. From that time on, the interest on the part of the common people has grown as knowledge of the facts has been constantly accumulated by the scientific workers. To-day the progressive leaders on every hand are striving to master all the known facts of inheritance in order that they may go about their tasks more systematically. Reformers, teachers, ministers, and officers of the law are beginning to recognize that their success depends in a great measure upon a knowledge of the theory and application of these principles of inheritance. In the *Illustrated World* (Vol. 24) may be found an interesting account of how the practical problems of Mendelism were applied in police service. Chief Vallmer, of the Berkeley Police Department, thought that these "impractical" principles of heredity were of sufficient importance to be given as a course of study to his men. He observed that a working knowledge of the facts of Mendelism made his policemen more competent in handling criminals and degenerates, in making arrests, and in checking the prevalent tendencies of crime among the people under their supervision. The Mendelian laws of heredity and transmission of characteristics, together with the influence of environment, were discussed by these officers at frequent intervals. One of Vallmer's men expressed himself in one of his weekly reports thus: "The question arises as to what ought to be done with the moral imbecile, not with the professional criminal to whom *wrong is a business.* The first thing to be done is to recognize him; and all these problems are enormously simplified if we can discover these traits at the beginning. We can, then, treat them as we treat all mental defectives." An officer was sitting in the station, when a pickpocket who had been arrested at a football game, passed by. "Look at that man," said the officer, "he is in this class" (pointing to one of the pictures in the chart he was studying). "He is mentally weak and should not be allowed to marry if the Mendelian theory of heredity is correct. It is the breeding of this type of individuals that causes much of our crime." This ability to recognize the degenerate and subnormal side of character in men is of great value in police work. In all large cities, the experiences of many years have brought out the principle that in the degenerate is to be found the solution to nearly all the problems involving crime. This principle, until now, has been ignored entirely too much. If a murder, an assault, or a robbery has been committed in a community, the first move in locating the perpetrator would be to account for the actions of all the degenerate and subnormal persons in that vicinity.

The Absurd Versus the Reasonable.—Regardless of the fact that the thinking class on every hand is recognizing the practicability of the underlying principles governing human inheritance, we are still confronted with a few non-progressive individuals who are continually strewing their antiquated principles in the path of human progress. However absurd it may seem, the following startling remarks were written in the latter part of 1918, and published in American periodicals which are supposed to be reliable.

1. "*Weismann ——— palmed it* (the germ plasm theory) *off on an unsophisticated public as something new in science.*"

2. "*Our biologists and eugenists carefully avoid reference*

to Providence and evil spirits, but they teach a doctrine having the same superstitious foundation."

3. "*The eugenist is a fatalist. He also subscribes to the old theological doctrine of eternal damnation.*"

4. "*The eugenists are largely absurd.*"

5. "*Eugenics is abortive both as a science and an art.*"

6. "*The eugenic doctrine based upon current teaching is a dismal and futile science.*"

7. "*The race is improved by improving the individual.*"

8. "*The child inherits what the parents have at the time of reproduction, and not what the parents had at some earlier time.*"

9. "*The parent may cause his child to be born better or inferior to himself according to the extent to which he has developed his own powers by exercise before the child was conceived.*"

10. "*The Jukes became feeble-minded as a family by reason of using immature-minded* (rather than feeble-minded) *persons as fathers and mothers for several generations in succession. The same result will inevitably follow from continued reproduction by youthful parents, no matter what the original stock may be.*"

To the trained biologist, and, indeed, to the more intelligent public, such sayings as the above would be taken as appropriate utterances of one of the earlier students of Lamarck (1744-1829). If the words of such alarmists are to be relied upon, the substantial works of all the biologists, from Weismann to the most recent investigator, should be relegated to the world of oblivion, and the race should start again more than a hundred years back with the meager knowledge that Lamarck and his co-workers possessed. To say that the doctrines of biology and eugenics are founded upon superstition, that the child inherits the physical acquirements of the parents, that feeble-mindedness is the direct result of early marriages, and that the eugenicists are "absurd" and are "fatalists" and that their doctrine is "abortive" and a "dismal and futile science"; to make these dogmatic statements without presenting substantial proof is entirely too *revolutionary* for even the greatest of living scientists.

Fig. 95. Is the giraffe's neck long because he picks the foliage off the high limbs, or does he reach the high limbs because he possesses a long neck? (See Chapter XXIX.) (From Jordan, Kellogg and Heath, by permission of D. Appleton & Co.)

Even though there are a number of writers promulgating their antiquated views at the present day, the consensus of opinion is to the effect that great hope can be placed in the eugenic doctrine. In a later chapter an attempt will be made to show the futility of any writers suggesting at this stage of development of our knowledge of inheritance that the giraffe's neck (Fig. 95) was made long thru stretching in an attempt to reach the foliage of the trees, that the kangaroo's

Fig. 96. After years of Christian agitation against foot-binding, Chinese leaders themselves undertook this reform. (From *World Outlook*, August, 1918, by courtesy of *Christian Herald*.)

forelegs disappeared thru non-use, or that the mole rubbed his ears off while passing thru his burrows. As a preliminary thought, it might be asked, *if* these are facts, why are the Chinese children not born with deformed feet (Figs. 96 and 97), since the binding of the feet of Chinese women has been practiced for thousands of years? If "the race is improved by improving the individual" thru "exercise before the child was conceived," then the Alpine guides *are sturdy because their fathers were mountain climbers before them*, and the arm of the blacksmith's child *will be large because his father developed* *a muscular arm.* How simple the whole process of race development would be if "the child inherits what the parents have at the time of reproduction, and not what the parents had at some earlier time." Were this true, the children of the athletes, blacksmiths, and mountain climbers would propagate a sturdy

Fig. 97. Although the parents and early ancestors of this Chinese child, for thousands of years back, practiced foot binding, it was born with plump feet with expanding toes. (From *World Outlook,* 1918, by courtesy of *Christian Herald.*)

race, while the progeny of the banker, the office clerk, and the teacher would be doomed to live as weaklings. Do observations of the facts substantiate these absurd assumptions? How would it be possible for the enlargement of a muscle, say of the forearm, to upset the germ cell mechanism, and thus cause the unconceived child to have strong arms? The absurdity is more obvious when we are reminded that the determiner for arm size is tucked away, not only in the germ cell, but in a definite chromosome which is delicately suspended in the karyoplasm of the nucleus.

To say that our defectives are produced thru the mating of youthful parents, indeed, is to dub one's self as a "revolutionist." Such utterances can never be supported by a systematic investigation of facts. How could it be possible for such things to be true if we accept the Mendelian ratios, which have long since proved to be the final death blow to Lamarckism? Is it not contradictory to say that certain characters arise by these haphazard methods, and then to state that they are inherited in a definite ratio? If the latter is true, the former must be false. In fact, an analysis of the vital elements of human inheritance will suffice to overthrow any such preconceived views. This method of constructive argument, as presented in the following chapters, is especially convincing when the relation between human inheritance and the Mendelian ratios is kept in mind.

CHAPTER XXII

NEGRO-WHITE CROSSES

"Blended" Inheritance—Production of Pink Four O'clock—Inheritance of Color in Cattle—Mendelian Inheritance of Human Skin Color—The Problem Applied.

"After all there is but one race—humanity."

—*Moore.*

Although a few cases of inheritance have been worked out which depart from the Mendelian ratio, they usually follow some fixed system. The haphazard method of handing down characteristics to the offspring is, therefore, almost unknown in the realms of heredity. As more and more knowledge is accumulated regarding the facts of Mendelian inheritance, many doubtful cases are brought under the law, or the principles themselves are extended and satisfactory explanations found for the supposed exceptions. One of the most common and indeed the first observed of these apparent exceptions to the Mendelian principle is classed under the head of "*Blended*" *Inheritance* or *Incomplete Dominance*. For example, when the red four o'clock (Fig. 98) is crossed with a white one of the same species, *pink* offspring rather than the expected red or white will be produced. The pink flowers are the usual hybrids resulting from such a cross and will produce when planted, the expected Mendelian ratio—one-fourth pure red, one-half hybrid pink, and one-fourth pure white (Fig. 98). In like manner, when red and white cattle are crossed the offspring are usually roans. The fact that roans are the intermediate blended hybrids permits the expected segregation into the ratio of 1:2:1—red, hybrid roans, and white.

Many cases of "blending" are now explained on the basis of the multiple factor hypothesis; that is, it is found that more than one set of factors are involved in the production of certain characteristics. In the above cases of incomplete dominance the characteristics of each parent which blended in the

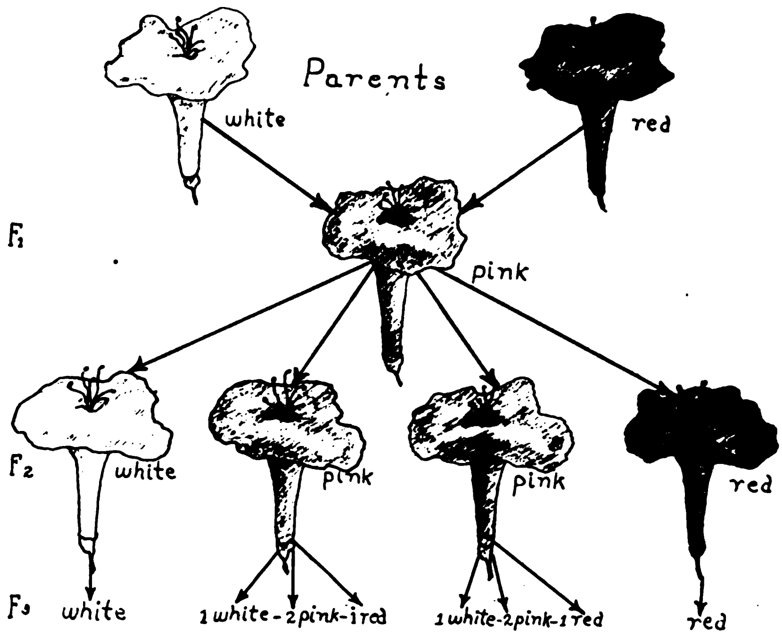

FIG. 98. Diagram illustrating the results of crossing white and red four-o'clocks. (Modified diagrammatically from Morgan.) If one should compare the four-o'clocks with a corresponding cross between the white and the black race (Fig. 99), the pink four-o'clock (F) would be comparable to a *mulatto*. However, the Mendelian 1:2:1 segregation does not take place when *mulattos* produce children. This shows that other factors are involved in the production of human skin color.

first generation separated in the second generation in the usual 1:2:1 ratio. We would very naturally conclude from this that the children of *mulatto* parents (Negro-White hybrids) would be one-fourth black, one-half mulatto, and one-fourth white. However, certain investigation into negro-white crosses which were carried out by Davenport have revealed the fact that such is not the case. The children of mulattos appear in the ratio of one white and one black child out of sixteen—the remaining fourteen being mixed white and black. The fact that there is a definite ratio in the progeny of black and white parents indicates that the solution of the inheritance of human skin color may eventually be solved on the basis of Mendelian principles. This particular ratio (1:15) further shows that more than one factor is involved in black skin pigmentation.

♀ \ ♂	AB	A	B	
AB	AB AB 1	A AB 2	B AB 3	AB 4
A	A AB 5	AA 6	AB 7	A 8
B	B AB 9	AB 10	BB 11	B 12
	AB 13	A 14	B 15	16

FIG. 99. Diagram explaining the 1:15 ratio obtained when *mulattos* reproduce. Since a double dose of both factors A and B is essential to the production of a pure black race, only one (square 1) out of every sixteen children will be full-blooded African type. The same proportion of white children will be produced since only one square (16) has neither of the factors for skin pigmentation. The remaining fourteen children (squares 2 to 15, inclusive) will be intergrades between black and white.

In fact, Davenport concluded that "*there are two factors (A and B) for black pigmentation in the full-blooded negro of the west coast of Africa, and these are separately inheritable.*" All indications seem to point to the fact that skin color segregates in accordance with Mendelian principles, rather than blending in all generations as is usually thought to be the case. The eggs or sperms of a mulatto may contain A and B, A, B, or neither of the two. There are only sixteen possible crosses between these various types of germ cells (Fig. 99). Of these, only one will be a full-blooded African negro—AABB (square 1). In no other case will an individual possess a double dose of both factors, A and B, which are essential to the production of the pure black type. On the other hand, only one (square 16) out of every sixteen offspring has neither the A nor B factor. These, of course, would be pure white. The remaining fourteen would represent various blends.

Davenport suggests in substance the following interesting facts: Skin color and woolly hair are not linked factors but are closely associated in an accidental way. They may segregate, and thus a person with woolly hair *may be part negro* although possessing white skin and passing for white. His veins may contain *more negro blood* than those of some other person who has been ostracized from "white" society. The low state of mentality of the *black* race has caused a certain resentment of their intrusion into our society. Separate schools, passenger cars, etc., which are usually inferior in quality, are assigned to these black people. Many negroes may possess the mental strength and pure talent that are often exhibited by superior white people, but their black skin places them in an inferior class. Many whites may possess low "black" intellect but are still members of our intelligent "white" society. Some white people who would consider it a disgrace to sit beside a colored person of most superior ability would not hesitate a moment to move into the company of a person of the most vile character provided his skin be white. Too bad we let skin color, rather than character and ability, determine the make-up of our society!

The germ plasms of the white race and the black race are intermingled in a large percentage of the ten millions of colored people who make America their home. Humphrey says: "Nature decrees that the Aryan shall pay dearly for his forcible crossings with inferior peoples. That decree is written upon the vanishing ruins of every dead civilization. And so now in America, a tenth of our population is of Negro blood in some degree, grafted upon us by the unbreakable ties of blood infusion. Why talk of deporting to their African home a people whom no one can separate into White and Black? Why talk of the Negro-White as either Negro or White?"

Davenport has given us the following interesting facts with regard to crosses between negroes and whites: "Every student of the negro-white crosses at Bermuda and Jamaica soon hears of the 'fixed white.' One of the most prominent Jamaicans thus defined the term: Fixed whites are those who not only 'pass for white' but also breed all pure whites; and he estimates that five or six generations at least are necessary for this. 'Pass for white' is used to indicate those who appear white, but some of these may have had darker children. In Jamaica, as indeed in some of our Southern States, after a certain dilution with white blood the descendant of an African becomes white by law. Thus in Florida a white man may not legally marry a mulatto (intermarriage of pure white and pure negro), a quadroon (intermarriage between a pure white and a mulatto), or an octoroon (intermarriage of pure white and quadroon), but may marry the daughter of a white man and an octoroon.

"Now, what biological basis have these social distinctions? It follows from our studies that persons of African descent whose skin color contains 10 per cent or less of black pigment will, if mated with a like person, produce only white skinned children—*i.e.*, with less than 12 per cent of black in the skin. Such persons constitute 'fixed whites.' Many persons of African descent who have between 10 and 15 per cent black in skin color are really hardly darker than dark brunettes or Spaniards; they may 'pass for whites,' but two such may have a medium-colored child. The outcome of such a marriage would, then, satisfy the definition of 'pass for white' and justify the appellation of the term in this case. As for the 'less than one-eighth blood,' it appears from our study that a mulatto has two units of black, a quadroon one unit, and an octoroon no unit for negro black pigmentation. Certainly the offspring of such an octoroon and a white person will, so far as skin color goes, be a 'white person.' Our studies, then, justify the legal limitation, so far as skin color goes. Indeed, a person of one-eighth blood is, so far as skin color goes, completely 'across the line'; married to white there is no exception of dark-skinned offspring, tho the hair may be curly and the lips thick.

"This brings us to a matter of great social moment to hundreds of our citizens; namely, the possibility of a reversion in the offspring of a white-skinned descendant of a negro to the brown skin color. There is even a current opinion that such an extracted white, married to a pure-bred white, may have a 'black' child. This tradition has been used to create dramatic situations in novels and in newspaper 'stories'; and the dread of this tradition hangs over many a marriage that would otherwise be quite happy. *In our studies no clear case of this sort has been found, and our fundamental hypothesis leads us not to expect it.*"

CHAPTER XXIII

THE INHERITANCE OF SEX

Erroneous Notions Regarding Sex Determination—Scientific View—Sex, a Problem of Heredity—Sex Production vs. Environment—Cause of Overproduction of One Sex.

A child is expected in the home. The mother, in one case, prepares the layette in blue, because her sole desire is for the newcomer to be a girl; but, all materials are inappropriate when a boy makes his appearance. In another instance, the reverse might be the experience. Then comes the expression, "Isn't it too bad that we had no way of knowing?" Perchance the extremist might scorn the scientist for not working out some method by which the desired sex could be produced at will; but, on the other hand, it is well that such has not been done. To be able to do this, however, would be of great value to the breeders of certain animals, where one sex is more desirable than the other. The poultry raiser, for example, would at times be pleased to raise all hens rather than only fifty per cent. of the total number of fowls.

Many ideas have been held in the past regarding the determination of sex. Most of these are popular notions and are nothing more nor less than superstitions. To some, it is enough to say that "God made male and female." However, many are unwilling to accept any such statement as a complete explanation. A typical example of popular ideas regarding sex determination is attributed by a certain author to the common people of Servia. There it is believed that if a father has a stye on his upper eyelid the child will be a male, if on the lower lid the child will be a female. At one time it was suggested that the right ovary was the seat of one sex and the left ovary the seat of the other. Several plausible explanations for influencing the sex of the future individual have been advanced by scientific men. These fall into two classes; namely, environmental and hereditary. The former of these two classes has for its basis the supposition that sex is determined by influences at work in the various environmental factors; the other attributes sex to purely internal causes that are entirely beyond the reach of external conditions.

The internal causes for sex refer to those agencies within the germ cell itself which have no dependence upon outside agencies or are not influenced by external factors. The chromosome theory for sex determination falls under this class. The majority of present-day biologists look to this theory for a real explanation of sex. They are, moreover, able to see that the Mendelian principles are involved in the production of sex as well as the other usual characteristics of the individual. Had the laws of Mendelian inheritance been known by the early workers, groundless hypotheses and absurd speculations regarding sex determination, as well as many other "biological principles," would never have been advanced. The parents might discuss the probability of the expected child's inheriting dark hair, or blue eyes; but it is not realized by them that the puzzling problem of sex may be solved by the same principles of Mendelian heredity.

A reconsideration of the chromosome theory (Chapter XIV) will assist in solving this query of sex from the Mendelian standpoint. It will be remembered that the male and the female chromosomes are alike if the sex-producing chromosome be left out of consideration. A reference to the equations on pages 227 and 228 will show that the female has twice as many (or as much, if considered quantitatively instead of numerically) sex-chromosomes as the male; in other words, the female has a double dose (is homozygous with respect to sex) of that something which determines sex while the male has only a single dose (is heterozygous). This suggests that a double dose of sex is necessary in order to bring out the dominant characteristics with reference to sex. In this respect, femaleness might be considered dominant over maleness since it takes a double dose of sex determiner to produce a female and only a single dose to produce a male. It will be remembered that in the case illustrated in Chapter XIV, one-half of the mature spermatozoa contained one sex-chromosome and the other half contained none.

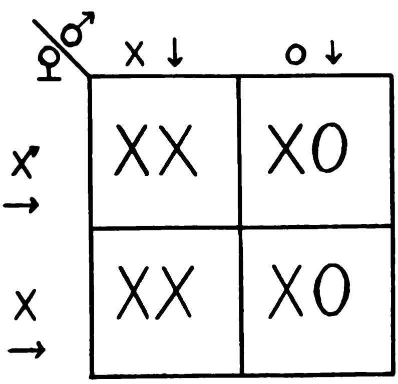

FIG. 100. Mendelian Inheritance of Sex—the relation between maleness and femaleness. Since the father contributes either an X or an O, and the mother always sends to her offspring an X, one-half of all children will contain an XX in their cells and the other half XO. The former will be girls and the latter boys.

Representing the male germ cell which contains a sex element by X and the one in which this element is absent by O, and representing the female gametes by X, since all eggs contain the sex-chromosome, the scheme illustrated in Figure 100 should show the Mendelian relationship between maleness and femaleness. Since the female has two sex-chromosomes, and the male only one, all the squares which contain XX will represent females and those with XO will represent males, giving an equal number of each. That is, when considered from the standpoint of gametes, the Mendelian ratio between the number of males and the number of females is 1:1. The cases considered in Chapter XIV in which there is more than one sex-chromosome can be represented by this same diagram. In cases where there are two sex elements, twice the number of X's will appear in each place. However, the resulting ratio will remain the same as in the case of a single sex-chromosome.

It must not be concluded that the so-called "sex-chromosome" is the absolute producer of sex. It should rather be thought of as the chromosome which carries the *determiner of sex.* Conklin suggests that sex is the "result of the interaction of many intrinsic and extrinsic causes." The X-chromosome is, however, in all probability the greatest factor in sex determination, as it is the carrier of the sex determiner. Since sex is inherited in the 1:1 Mendelian ratio, it seems impossible to influence the sex of higher animals in any way.

The environmental theory for sex determination includes all agencies *outside* of the germ cell (not necessarily outside of the body) which may influence sex. As the germ cells receive their nutrition from the blood, the same as do the somatic cells, some biologists hold the opinion that this factor has much to do with the determination of the character of that cell, not only from the standpoint of cellular health but also from the standpoint of its potentialities for sex.

A number of workers have reported experiments with certain lower forms in which the sex ratio was affected. Chief among these are Hertwig, and Miss King. The former caused frogs' eggs to develop into 100 per cent males by allowing them to absorb water in the process of ripening before fertilization; the latter, using toads' eggs, performed the opposite of Hertwig's experiments and obtained the expected opposite result —90 per cent females.

Riddle, working with pigeons, has gone very much into detail regarding the physiological conditions within the cells of both male and female. He has found that they differ in very striking ways, the male cells possessing a high percentage of water, low percentage of fat and phosphorus, and high metabolism, the reverse of this condition representing the physiological make-up of the female. According to this conception, any environmental factors that would alter the physiological make-up of the germ cells would in turn influence the sex of the next generation. These results were obtained by forcing abnormal conditions upon the eggs. Normally, the ratio of the sexes would have remained substantially unaltered and the production of almost an equal number of males and females would have taken place. This is especially true of the higher animals and man.

The question might arise: If sex is inherited in a definite 1:1 ratio, why do we sometimes find families in which all or

FIG. 101. Predominance of one sex from the same parents. Sex is explained on the basis of the chromosome behavior. By chance only the spermatozoa bearing the female producing element were used in producing this family of ten daughters.

a majority of the children are of one sex? In this connection, it should be remembered that all the laws of inheritance not only apply to every ova and sperm that is formed, but they assume the complete development of all. In the human, for example, it has been estimated that over 300 billions of spermatozoa are formed in a lifetime. From this vast number, perhaps only four may be used to fertilize ova and develop into children. One could easily perceive how, by the *law of chance*, all of the four sperms which were used might accidentally have come from the 150 billion spermatozoa that carried the determiner for femaleness and thus all the children be girls. Such is, in all probability, a common occurrence not only in sex production but in heredity in general. The author is personally acquainted with one family in which all of the ten children are of the same sex—girls (Fig. 101). Unquestionably, one-half of all the sperms produced lacked the sex-chromosome which carried the determiner for femaleness, but, according to the law of chance, none of these were used to fertilize an ovum. But, in the face of this fact, we find families with many sons, but without a single daughter. In such cases, it probably so happened that all the children were produced from the sperms which did not contain this sex element. The law of sex inheritance certainly will not hold good if the children from any one particular family are considered alone. But if the children from a large number of parents are considered, it will be found that the number of boys and girls will be practically equal. Such is the case with any particular character. Before any definite conclusion can be reached, a very large number of individuals must be taken into consideration.

CHAPTER XXIV

INHERITANCE OF FEEBLE-MINDEDNESS

Goddard's Data—Types of Parents—Both Parents Feeble-minded—One Parent Feeble-minded, Other Normal—Both Parents "Carriers"—One Parent Feeble-minded, Other "Carrier"—One Parent "Carrier," Other Normal—Fate of the Children.

"Babylon in all its desolation is a sight not so awful as that of the human mind in ruins."

—Davies.

"Mental and moral features of different races are equally fixed by heredity. The dogged determination of one race, the emotionalism and idealism of another, the arrogance, the love of gain, the irresponsibility, the deception, the sturdy honesty of other races, are all inherited traits."

—Shull.

Feeble-Mindedness (Fig. 102).—The more there is known about families having feeble-minded members, the more substantial is the proof that the inheritance of this defect falls into direct line with the Mendelian law. The extensive works of Goddard, especially, reveal this fact. The accompanying chart gives the actual data of five types of mating (indicated in the first column) where feeble-mindedness was involved. *FF* indicates a double dose of feeble-mindedness, *NN* indicates a double dose of normality. *NF* indicates a single dose of each. The first type of mating ($FF \times FF$) would thus read: A feeble-minded man marries a feeble-minded woman, or the reverse. The fourth type ($FF \times NF$) means that one parent was pure feeble-minded while the other carried only a single factor for the defect.

FIG. 102. How selfish is so-called civilized man! He establishes institutions to care for the defectives in order that they may be out of his way, but seldom attempts to prevent the next generation of defectives from crowding his children.

Type of mating	Number of individuals studied	Feeble-minded offspring		Normal offspring	
		Actual Finding	Theoretical Mendelian expectations	Actual Finding	Theoretical Mendelian expectations
I FF X FF	482	476	482	6	0
II FF X NN	34	0	0	34	34
III NF X NF	146	39	36½	107	109½
IV FF X NF	371	193	185½	178	185½
V. NF X NN	23	0	0	23	23

(Chart modified from data collected by Goddard)

A sixth type which might have been tabulated would be expressed thus: NN × NN; that is, both father and mother are from a pure line of normal parentage. In other words, they both possess a double dose of normality. When both parents are purely normal, the children are, with rare excep-

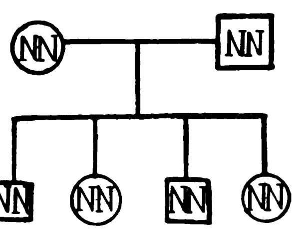

Fig. 103. If the father and mother are both normal, the children should be normal, except in rare instances of some embryological disturbance. No child was ever made deformed or feeble-minded by prenatal impressions, birth-marks and the like.

tions, also normal. These rare exceptions might be due to injury, or possibly to extreme variation such as mutations or "sports." This type of mating might be graphically represented as shown in Figure 103. In this figure the squares represent males, and the circles females; no significance is to be given to the sex of the offspring, as feeble-mindedness is just as likely to appear in a boy as in a girl. Feeble-mindedness is not a sex-linked characteristic, as is color-blindness (See Chapter XXVI). In each of the cases cited below the four offspring indicated are to be considered on a theoretical percentage basis; that is, if one is marked F and the other three N, one-fourth of all the children are feeble-minded, and three-fourths are normal.

Case I. FF (Feeble-minded) Father × *FF (Feeble-minded) Mother* (Fig. 104).—The first type of mating considered on the chart (Goddard's data), indicated FF × FF, includes parents both of whom are feeble-minded; that is,

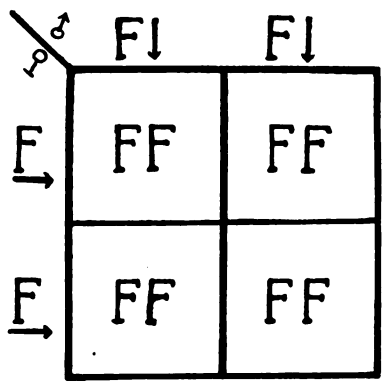

FIG. 104. In case both parents are feeble-minded, neither can transmit to their children factors for normality. All offspring will therefore possess a double dose of feeble-mindedness.

they both possess a double dose of the determiner for feeble-mindedness. To the reader who is not well-versed in Mendelian calculations, the column headed "theoretical Mendelian expectations" might be somewhat puzzling. In the type of mating under consideration, the meaning should be evident, since nothing but feeble-minded children would be expected from parents both of whom possess a double dose of that defect. Other cases will be more fully explained as they present themselves. The method of explaining the whole problem of inheritance on the basis of the union of the sperm and the egg should also apply to the inheritance of feeble-mindedness as well as it does to certain characteristics in garden peas, or any other plant or animal, since the factors which determine that defect in offspring certainly must be located in the germ cells of the parents. Since each parent is from a feeble-minded family, every sperm and every ovum (egg) carries that factor which stands for feeble-mindedness; or, to express it on the

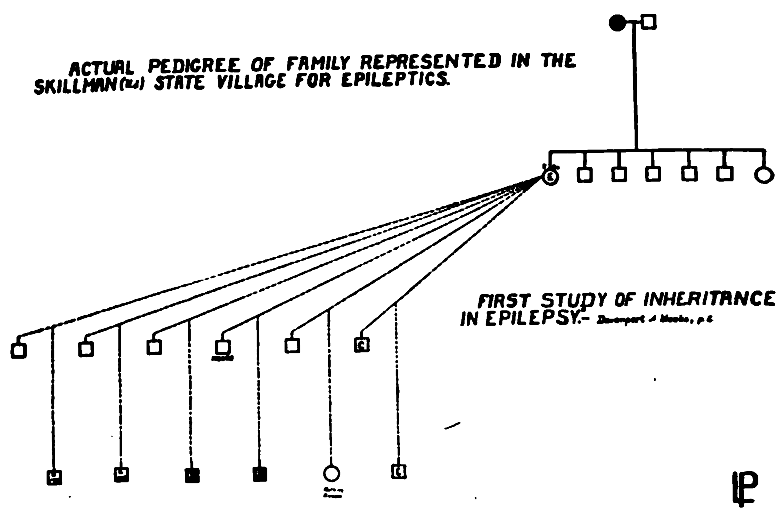

FIG. 105. Diagram illustrating the origin of many feeble-minded and otherwise defective children. Note that the daughter of a feeble-minded mother, without having been married, produced six illegitimate offspring from six different men, one a negro. Two of these children died in infancy (characteristic of feeble-minded people), two were feeble-minded, and one epileptic. Would it not have been a blessing to humanity had this mother been confined in an institution or sterilized when a girl? (From Eugenic Record Office, after Davenport and Weeks.)

basis of the presence and absence hypothesis, the character which causes the individual to be normal is absent from all spermatozoa and eggs, or *gametes*. Therefore, as shown in the accompanying diagram (Fig. 104), all *zygotes* (offspring) will carry a double dose of feeble-mindedness (FF). The theoretical expectation, therefore, should be equal to the number of children whose mentality was determined and who are produced by such parents. With reference to the first type of mating indicated on the chart, it will be noted that in the words of Goddard: "Of 482 children, of parents both of whom were feeble-minded, all were feeble-minded, with the exception of six. The exceptions are so few as to be hardly worth consideration. It is very probable, moreover, that some of these are to be explained by a possible error in judgment. These six may not be as normal as they appear. Further experience with them might show that they are below the level."

A further explanation for the variations from the law might be found in the fact that the supposed parent was not the real parent. Sexual immorality often accompanies feeble-mindedness (Fig. 105). Goddard calls our attention to the fact that Dr. Emerick of Columbus, Ohio, has traced the records of an interesting family composed of a feeble-minded father, a feeble-minded mother, and twelve children, ten of whom were feeble-minded. The two normal children were colored. If the two normal children had been white, this family might have been cited to prove that feeble-mindedness does not conform to the Mendelian law. However, under the existing circumstances, it is evident that the feeble-minded man was not the father of the two normal boys. Therefore, according to the law of Mendelian inheritance, which seems to be substantiated by observed and tabulated facts, we seem justified in concluding that all children, excepting accident and variation, from normal parents will be normal; and all children from feeble-minded parents will be afflicted.

Case II. FF Father × NN (Normal) Mother (Or the Reverse) (Fig. 106).—It is strikingly interesting to note the result of a marriage when one of the parents is feeble-minded and the other normal. (See Chart, Type II Mating.) By referring to the Mendelian table, we can see the fate of every child decreed by the living germ cells. Suppose the father to be the unfortunate one and the mother to be a normal woman. The arrows on the figure 106 indicate that every paternal gamete shall be an F and that every maternal one shall be an N. Consequently the germ cells of every child shall be branded "NF." How can a child be both normal and feeble-minded? In terms of Mendelism, they are ***hybrids.*** It is very fortunate for them that the factor which stands for normality is dominant and that the one which stands for feeble-mindedness is recessive. They should, therefore, all be normal children; that is, the theoretical number should be the same as the number studied. A glance at the chart will show that of the thirty-four individuals studied, having one feeble-

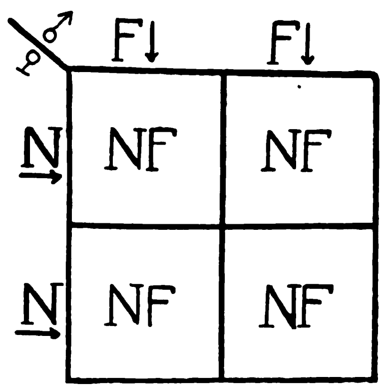

Fig. 106. When one parent is normal (NN) and the other feeble-minded (FF) all children should be apparently normal (Carriers, NF), but carry feeble-mindedness to their children.

minded parent, all were normal. Very unfortunate, however, for the human race that these children were destined to be *NF* instead of *NN*. True, so far as their individual success is concerned, there will be no difference. But, *NN* means a *pure* germ cell and *NF* means one which is *polluted* with that undesirable something which causes feeble-mindedness to crop out in later generations.

Case III. NF Father × *NF Mother* (Fig. 107).—In this type, both parents are normal but they carry a factor for feeble-mindedness in their germ cells (NF); that is to say, they are "carriers." When the gametes are separated, each parent will contribute either an N or an F and no power can choose which it will be. It must be left to the law of chance. Again, the figure answers the fate of the children (Fig. 107). The offspring indicated by the first square (NN) will be purely normal, since the dominant characters of both parents are here united, giving a double dose of normality. The children indicated by the second square (NF) receive a factor for

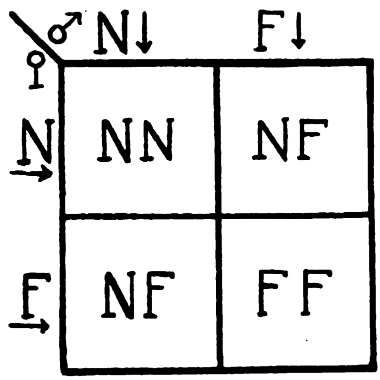

Fig. 107. The figure suggests at least one explanation for the production of a feeble-minded child by two "Normal" parents. A woman or man of even superior mental ability might be a "carrier" of feeble-mindedness. (See text.)

feeble-mindedness from the father and a factor for normality from the mother, while the reverse is true of the third square, the end result, however, remaining the same. The unfortunates indicated by the fourth square possess a double dose of feeble-mindedness, since each parent contributes an F gamete. Can it be true that apparently normal people will produce children with such different characteristics; one-fourth NN, one-half NF, and one-fourth FF? Here in our dealings with the human race, we find our old friend, the 1:2:1 ratio. It is evident that the one-fourth marked NN is the beginning of a new untainted line of normal people, and that those branded NF are normal in outward appearance but possess tainted germ plasms. Is it true that the FF children are to be feeble-minded even tho their parents were apparently normal? This is so unbelievable that it seems wise to apply the mathematical check method used in dealing with other Mendelian factors.

$$\begin{array}{l} N + F \\ N + F \\ \hline NN + NF \\ \quad\quad NF + FF \\ \hline NN + 2NF + FF \end{array}$$

Three-fourths of the children from parents who appear normal but "carry" impure germ cells will be normal, tho part hybrids, and the other one-fourth will be feeble-minded. Of the one hundred forty-six individuals studied by Goddard (Chart, Type III), thirty-six and one-half (one-fourth) should have been feeble-minded, and one hundred nine and one-half should have been normal. The actual finding was thirty-nine of the former and one hundred seven of the latter—a non-considerable difference. Is this not a strange mixture of mathematics and biology?

Case IV. FF Father × *NF Mother* (*or the Reverse*) (Fig. 108).—What an unfortunate group of children is produced from parents one of whom is purely feeble-minded (FF) and the other normal in all appearances but carrying in the germ cells a factor for feeble-mindedness. It is a veritable Arabian Night story how our Mendelian theoretical chart can inform us on the beautiful wedding day as to the fate of the poor unfortunates which will result from such a mating. Since one parent carries no determiner for normality and the other only one, one-half of all children will be FF and the other half hybrids (NF). The former will all be afflicted, while the latter will be normal but will produce feeble-minded offspring in the proportion shown in Case III. A reference to Goddard's chart will show that the theoretical results of the type differed but little from the actual facts as he found them.

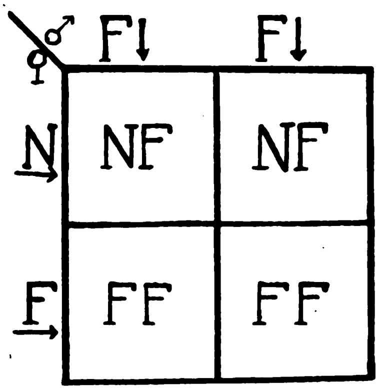

Fig. 108. In case one parent is normal, but is a carrier of feeble-mindedness, and the other parent is truly feeble-minded, one-half of the children will appear normal but will possess "impure" germ cells, while the other half will be feeble-minded.

Case V. NN Father × NF Mother (Or the Reverse) (Fig. 109).—The marriage of a normal (NN) man to a hybrid ("Carrier," NF) woman who carries tainted germ cells

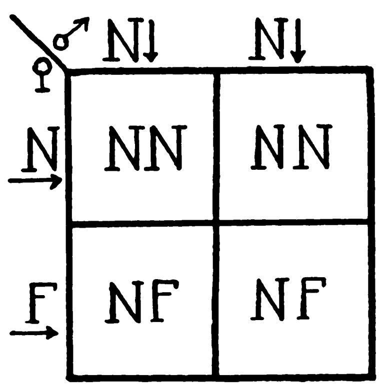

Fig. 109. When one parent is normal and the other a "carrier" one-half of the children will be normal and the other half "carriers."

is less deplorable but equally as interesting. Figure 109 shows that the normal gamete from the woman will meet the N gametes of the man in half of the squares, thus producing fifty per cent of purely normal children. The F gamete, on the other hand, will, when united with the male gamete, produce NF zygotes which will cause the other half of the children to appear normal (since N is dominant over F) but to carry to their children in a later generation that dreaded determiner for feeble-mindedness. Every child would from all outward appearances be absolutely normal, and the facts as found by Goddard agree exactly with our expectations.

Summary.—A review of the small figures given above will show that both the Mendelian laws and the actual facts of the cases studied justify the following conclusions: Normal parents produce only normal children and feeble-minded parents produce only feeble-minded children. When one parent is normal (NN) and the other afflicted (FF), all the children appear normal, but in reality possess the power to transmit (if they marry their kind) feeble-mindedness to one-fourth of their children and normality to the other three-fourths (two-thirds of this three-fourths, however, will be like their parents; that is, normal themselves but possessing the quality to transmit feeble-mindedness to their own children). When one parent is feeble-minded (FF) and the other normal but carrying impure germ cells (NF), one-half of all their children will be feeble-minded (FF) and the other half normal (NF) with the power to transmit the defect. And, lastly, when one parent is normal (NN) and the other normal (NF), but with the F in the germ cells, all the children will be normal but one-half of them will carry the affliction to the next generation.

The relation between the Mendelian laws of inheritance and actual observed facts is further emphasized in the words of Goddard: "In the totals of all these matings, the expectations would be: feeble-minded 704, the actual 708; normal expectation 352, actual 348. Such results are difficult to account for on any other basis than that feeble-mindedness is transmitted in accordance with the Mendelian formula.

"Since our figures agree so closely with Mendelian expectation, and since there are few, if any, cases where the Mendelian formula does not fit the fact, the hypothesis seems to stand, viz.: Normal-mindedness is, or at least behaves like a unit character, is dominant, and is transmitted in accordance with the Mendelian law of inheritance" (Fig. 110).

FIG. 110. Mattie, crying out to "civilized" man in her "devilish cackle," "Why did you not refuse me birth since you could not let me be well born?" Mattie, aged 28, has two brothers in the same state institution, one being a bed case. Her mother and many other relatives are mental defectives.

Legislation should limit itself for the present to those characters which are of the greatest social importance and whose heredity is best known. FEEBLE-MINDEDNESS IS SUCH A CHARACTERISTIC, *and radical steps looking toward its eradication would be justified even in the present state of knowledge.*

—*Shull*, '20.

CHAPTER XXV

INHERITANCE OF VARIOUS MENTAL AND MORAL TRAITS

General Formula for Determining Characteristics of Offspring —So-called "Black Sheep"—Hereditary Diabetes—Marks of Beauty.

"Everything seems to indicate that alcoholism itself is only a symptom, that it for the most part occurs in families where there is some form of neurotic taint, especially feeble-mindedness. The percentage of our alcoholics that are feeble-minded is very great. Indeed, one may say without fear of dispute that more people are alcoholic because they are feeble-minded than vice versa."

—*Goddard.*

Other Defects.—If insanity, in its many and varied forms of appearance, is only an extreme type of feeble-mindedness; and, further, if the cause of criminality, sexuality, pauperism, and alcoholism is traceable to feeble-mindedness (Fig. 111), as seems to be the case, we would logically conclude that these characters are recessive to the normal condition. Reference to the reports (especially those of Rosanoff, Davenport, and Plate) of those who have made a study of family histories shows that this assumption is correct so far as facts have been ascertained. Galton was one of the earliest workers to establish the fact that exceptional mental qualities are inherited. Pearson and his supporters have shown that the principles of inheritance should include even such characters as popularity, temper, vivacity, conscientiousness, etc. When the laws which govern the inheritance of the various mental and temperamental attributes are worked out in detail, the problem of race improvement will be greatly simplified.

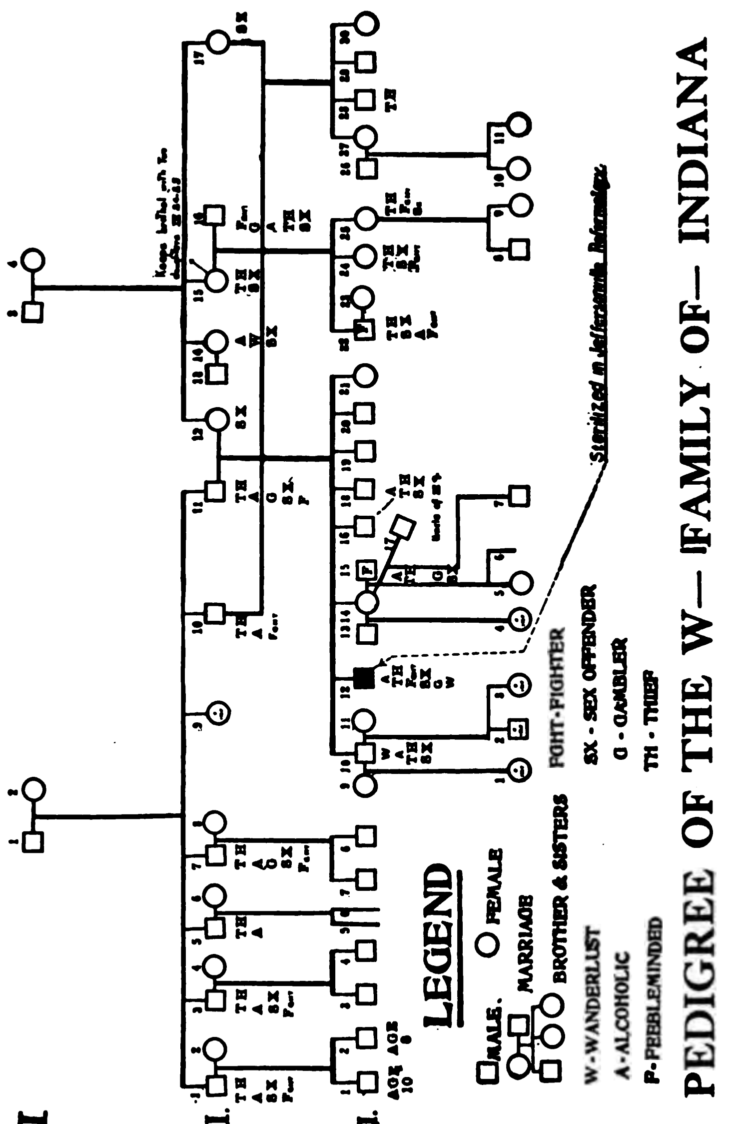

FIG. 111. A study of such family histories as indicated by the accompanying chart will establish the fact that various mental and moral qualities are handed down from one generation to another. Although similar environment is a vital factor in the further production of such defectives, the basic explanation lies in the realms of heredity. It is interesting to note that one individual (III, 12) was sterilized under the sterilization laws of Indiana. America would have a less number of inmates in state institutions had the four individuals indicated in the first generation been sterilized. (Pedigree chart, courtesy of Eugenic Record Office.)

When a few facts of one's family history are known, ***we are in a position to predict fairly accurately the type of children that will be produced.*** This method of prediction will be the same as that used in the theoretical tests for feeble-mindedness. If the letters which stand for the other recessive characters, I (insanity), C (criminality), S (sexuality), P (pauperism), and A (alcoholism), are substituted for F (feeble-mindedness), the discussion would apply to the respective cases in hand. However, it must be understood that since no complete data has been collected, as in the case of Goddard's data on feeble-mindedness, this application is largely theoretical. But facts, when collected, will probably substantiate the theory. Since it is vitally important that these principles be clearly understood, the application will be carried further by means of general figures which will show the results of each of the five types of matings when any of the characters mentioned above are under consideration.

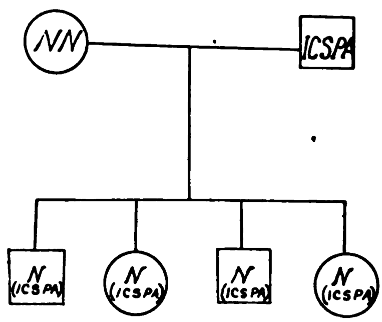

Fig. 112. A general diagram showing that when a normal parent is mated with a parent carrying certain defects, the children will appear normal but will possess the innate capacity to transmit the defect.

General Figure for Type I.—It will be remembered that under feeble-mindedness the first considered type of mating (Case I) assumed that both of the parents were afflicted. In order to determine the hereditary tendency of any one of the defects associated with feeble-mindedness in such a mating, it will only be necessary to substitute the letter for the character under consideration for F (feeble-mindedness). When any one defect is possessed by both the parents, all the children will, in like manner, be affected.

General Figure for Type II (Fig. 112).—If one parent is a "pure" subnormal with respect to any of the characters considered, and the other is a "pure" normal, all children will be normal but will transmit the defect to their offspring. This fact is shown by the accompanying figure (Fig. 112). The recessive characters are indicated by being placed in parentheses. For example, if the reader is interested in the nature

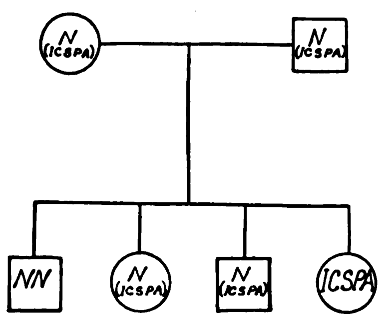

FIG. 113. When "carriers" of any recessive defect marry, they may expect one-fourth of their children to be pure normal, one-half "carriers" like themselves, and one-fourth defective. This accounts for many so-called "black-sheep" in the family.

of the children from parents one of whom carries a hereditary tendency for crime (C) and the other normal, strike out all letters on the figure except the C and the N. By so doing, one parent would be indicated C (criminality), and the other N (normal). All the children [N(C)] would be normal in all external appearances but would carry in their germs cells certain factors for criminality.

General Figure for Type III.—The children from the last-considered parents are all normal but carry defective germ plasms. By striking out all letters except the one standing for the character which is being examined, the figure (Fig. 113) shows that if such children intermarry with families like them, one-fourth of the offspring will be pure normal (NN), one-half after their kind [N(C), N(S), N(P), N(A), or N(I)], and one-fourth will be pure defectives (CC, SS, PP, AA, or II). However, it has been clearly shown that since N is dominant over all other characters, the one-half cannot be distinguished from the one-fourth that is pure normal until they marry and produce insane or sexually immoral children, criminals, paupers, or drunkards.

General Figure for Type IV.—Consider for a moment the nature of the offspring when one parent is a pure defective

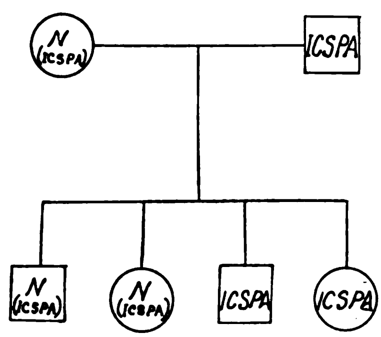

FIG. 114. If either parent is a "carrier" of a recessive defect and the other is purely defective in the same regard, one-half of the children will be defectives and the other half carriers.

and the other appears to be normal but possesses any one of the above defects in the germ cells. After applying the usual method of elimination, it should be clear (Fig. 114) that one-half of the children will be defectives and that the other half will be normal, but carrying the defective character in their germ cells to transmit to their children.

General Figure for Type V.—A similar generalization might be drawn from the fifth type of mating in which one parent is normal and the other is a hybrid—normal but with defective germ plasm. In this last case, suppose we desire to know the type of children that will be produced by the daughter of an inherent drunkard—assuming her married to a man from a family which possesses no inherent tendencies for strong drink. The girl may not have the least desire for alcoholic beverages but still she will pass the factor on to one-half of her unfortunate children as she is a hybrid [N(A)] in this regard. Since N is dominant, these children will not be likely to be drunkards but they will hand the defect down to their children as their mother handed it down to them. So long as these children marry those who are purely normal with respect to this defect, there will be no drunkards, so far as a hereditary tendency is concerned. But as soon as either a man or a woman of this mixed impure blood marries one of his kind, the problem will be reduced to Case III in which one-fourth of the children will be drunkards if great environmental pressure is not brought to bear upon them. This clearly shows how a drunkard might appear (as is often the case) in a seemingly pure family of total abstainers. In like manner, a thief or a sexually immoral character might suddenly appear in a family whose history has been perfect for hundreds of years. *Is it not possible that this is the explanation for the appearance of the "black sheep" in many respectable families?*

It will be noted from the following chart that, as a general rule, Normality is dominant over defects. However, many family histories have been traced in which abnormal conditions have been dominant.

If the question arises as to the number of children bearing these defects which would be produced as a result of certain marriages, a solution will be found from the figure under that particular type of mating. This will be seen by substituting the symbol for the defects of this last mentioned group for the N (as these characters are dominant). Specifically, parents of Mating Type I would have all children afflicted with these defects; from Type II, in like manner all children would be defective; from Type III, three-fourths defective; from

HUMAN CHARACTERISTICS INHERITED IN MENDELIAN FASHION

Dominant	*Recessive*
Hereditary Diabetes	Normality
Hereditary Blisters	Normality
Hereditary Cataract	Normality
Hereditary Night Blindness	Normality
Normality	Hereditary Epilepsy
Normality	Hereditary Feeble-mindedness
Normality	Hereditary Insanity
Normality	Hereditary Alcoholism
Normality	Hereditary Criminality
Normality	Hereditary Hysteria
Normality	Saint Vitus Dance
Average Intelligence	Very Great
Average Intelligence	Very Small
Nervous Temperament	Phlegmatic
Normality	Deaf-mutism
Normality	Dwarfism
Brachydactylism (Absence of one joint in toe or finger)	Normality
Polydactylism (Extra digits on hands and feet)	Normality
Syndactylism (Fig. 117) (Digits are fused side by side)	Normality
Normal Pigmentation	Albinism
Dark hair	Light hair
Curly hair	Straight hair
Black hair	Red hair
Dark skin	Light skin
Brown or Black eyes	Blue or Gray eyes

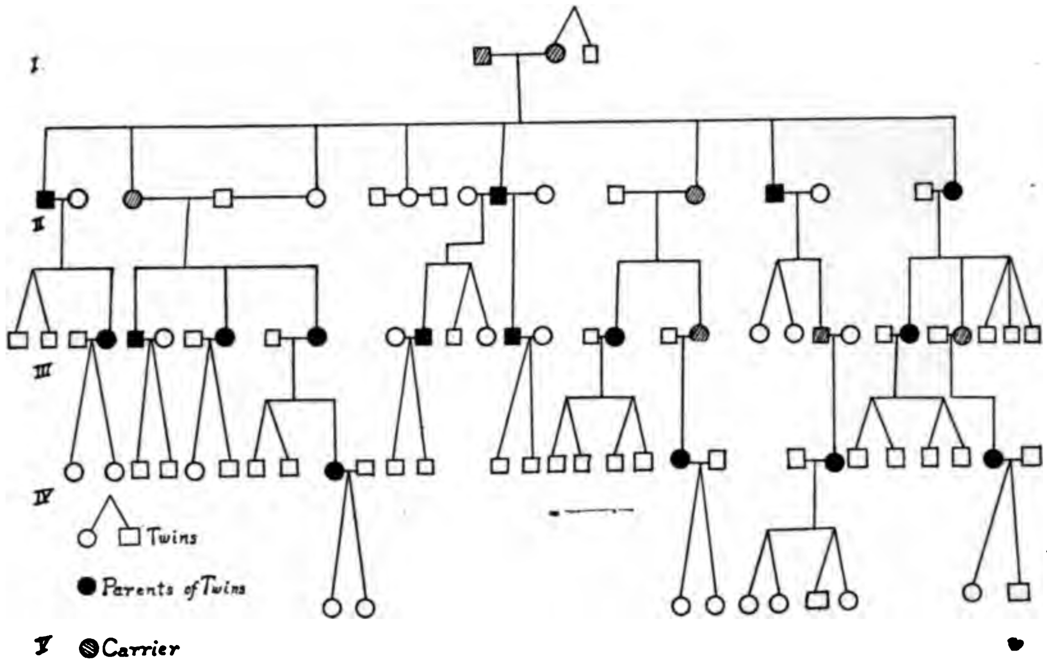

FIG. 115. The Inheritance of Twinning—the Blankenship Family. Among the scores of human characteristics which are inherited that of twinning is probably one of the last to be definitely established. The chart shows that the ability to produce twins (black squares and circles) is inherited thru five known generations. All individuals who were not twins or not direct ancestors of twins were omitted from the chart. Although data was not sufficient for a definite conclusion, the ability to produce twins seems to be a Mendelian recessive character in this Kansas family. (Investigation made by the author and Glen Martin, a student.)

Type IV, one-half defective; and from Type V, all would be defective.

Still other cases of Mendelian dominance and recessiveness are extremely interesting. Were you to apply for a position of great trust, your employer-to-be would not be very likely to consider, while judging your qualifications, the color of your hair or eyes or whether your skin was light or dark. However, the hair, eyes, and skin, as well as other marks of beauty, are used as the basis for individual description. Every person has set his own standards of beauty on this basis. Some admire dark hair and brown eyes, while others prefer light hair and blue eyes. This personal admiration has gone to such an extreme that heated debates are held in many homes on the origin of certain eye, hair, or skin color of certain children. Both parents may be very dark with brown eyes and black hair but a certain son is very light with blue eyes and red hair. How strange and puzzling is this combination of parents and son. Such cases have been known to be the basis for disputes between husband and wife and ultimately the cause for divorce. Since such a case was beyond expectation and even, to the parents, beyond possibility, the wife might have been accused of presenting an illegitimate child. The unusual child might present an almost exact resemblance to some man of the community who had already been accused of "too much attention." The author calls to mind one instance when the worthless husband claimed that his son was *birth marked for a neighbor man.* As his explanation for this absurd statement, he claimed that his wife so greatly admired the other man that *his own child,* when born, resembled his supposed rival.

Even tho hair, eye, and skin color is extremely perplexing to those who base their judgment on broad guesses and wild assumptions, the problem is very simple when viewed from the standpoint of Mendelism. As a working basis, it should be stated that investigations have revealed the fact that brown eyes are dominant over blue, dark hair dominant over light (including red), curly hair over straight, and dark skin is dominant over light skin. Having accepted these facts, let us seek a Mendelian explanation for the extreme case cited in which a son with red hair, blue eyes, and a very light complexion was born to parents both of whom were, seemingly, "pure" for dark skin, brown eyes, and black hair (Fig. 116). Let us assume that the unknown great-grandparents (PIII)

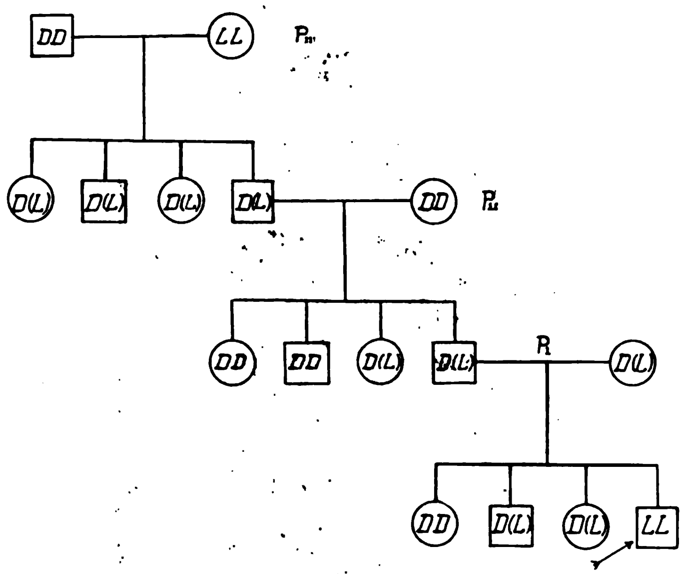

FIG. 116. Hypothetical family chart showing the possibility of a child possessing characteristics which are foreign to any of the known grandparents.

on both sides came under Mating Type II; that is, one had dark skin, brown eyes, and black hair (DD), while the other was light with blue eyes and light or red hair (LL). Since the dark complexion is dominant over the light, all children (grandparents of above boy) will be dark but will carry in their germ cells the determiners for blue eyes, light hair and skin. They will thus be indicated D(L). (See figure under Type II.) The grandparents, all of whom are known to be dark, marry those who are *pure* dark (DD). This mating falls under Type V, since it involves the mating of one individual with *pure* germ cells (DD) to another who is a *carrier* [D(L)]. The figure under Type V shows us that all the

FIG. 117. Syndactylism—fused fingers and toes—is a Mendelian dominant. Physical and mental defects ofttimes run hand in hand.

children from the above known dark grandparents will be dark, but one-half of them will carry factors for light.

Now it so happens (under our assumption) that individuals bearing this type [D(L)] of "impure" germ cells from their two families marry. That is to say, ***both the father and the mother of the boy are dark but they carry***

determiners for light skin, blue eyes, and light hair. This mating may be referred to Type III (Fig. 116), which tells us that one-fourth of all offspring would be light and have blue eyes and light, if not red, hair. Thus, the mysterious boy whose parents and grandparents were all dark appears in fulfillment of the natural Mendelian laws and expectations. Although the three characters (eye, hair, and skin color) often run hand in hand, as considered in this hypothetical case, each might be more or less independent of the other.

As time progresses, more of the characters of the human race will be studied and added to the remarkable Mendelian category. All honor is due to that Austrian wizard, Mendel, for his enchanting game with the peas, and to the three patient and substantial laborers of 1900—that memorable year which marks one of the greatest advances in human progress.

"No one doubts for a moment that defective mental conditions are transmitted from parent to child as surely as the physical defects and deformities. Every one knows that it is common for defectives to be attracted to each other and marry, and that the defects of both parents are liable to be transmitted to the children. It is also true that there are more children born in such families; and for that reason the percentage of defectives is continually on the increase. The report of the state of Illinois shows the increase to be alarming, and many other states are no better. *It is absolutely wicked that the persons suffering from periodical insanity should be allowed to return to their homes to propagate and scatter their children about the state as dependents.*"

—Gorst.

CHAPTER XXVI

"CRISS-CROSS" INHERITANCE

"Father to Daughter—Mother to Son" Inheritance—Color blind Man Marries "Carrier" Woman—Color-blind Man Marries Normal Woman—"Carrier" Woman Marries Normal Man—Both Parents Color-blind—Normal Man Marries a Color-blind Woman.

For a long time, the type of inheritance which comes up for consideration was so puzzling that no correlation could be seen between it and any of the Mendelian principles. Some defects and characteristics were known to be handed down from *father to daughter and from mother to son.* This peculiar behavior is known as "*criss-cross*" *inheritance* and has been worked out in detail. Many cases of it have been solved and found to fall under definite laws. Of these, a general consideration of but one case will suffice for the present explanation.

Human color-blindness (inability to distinguish a color from its compliment, as red from green) is extremely interesting from the standpoint of inheritance. It is perhaps the best known and most commonly observed instance of "criss-cross" inheritance. It is a significant fact that it requires a *double dose* of color-blindness to produce a color-blind woman, while only a single dose is required to affect the male. This is very suggestive of the requirements for the production of femaleness and maleness (See Chapter XXIII). As a result of this similarity of behavior it has been suggested that the factors which determine color-blindness are, when present, located in the sex-chromosomes. Color-blindness is, therefore, a type of *sex-linked inheritance.* There are five possible matings between color-blind, "carrier" and normal people in which color-blindness will either appear in the progeny as a characteristic or in his germ cells as a determiner of unborn generations. They are considered in the following pages.

Case I. Color-blind Man Marries a Normal Woman (Fig. 118).—It has been known for some time that should a color-blind man marry a normal woman none of the children resulting from the union would be color-blind. But, on the other hand, *all the daughters from such a mating would transmit the defect to certain of their sons*, depending upon the type of father (see cases II and III below). The daughters would,

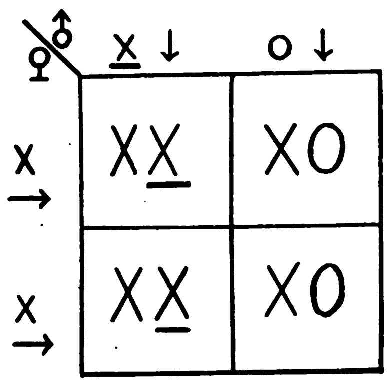

FIG. 118. When a color-blind man marries a normal woman, all the daughters will be carriers (XX) and all of the sons will be pure normal.

therefore, be "*carriers*" although not color-blind themselves. Such a puzzling case could never have been solved had it not been for the chromosomial explanation of the Mendelian ratios. Since color-blindness is linked with the sex-chromosomes, the common chromosomes are not considered in the figures herewith presented, as they play no part whatsoever in the mechanics under consideration.

Since, in our assumption (Fig. 118), we are mating a color-blind man with a normal woman, only the sex-chromosome which is brought in by the male will be "tainted." The affected chromosome which carries the factor for color-blindness is indicated by an X with a line placed beneath it. The

O stands for the male cell (gamete which has no sex-chromosome. Therefore, the first and the third squares (Fig. 118) will receive the affected X from the male and the normal X from the female and, thus, will produce individuals who will possess the factor for color-blindness but who will not be color-blind themselves. Since these individuals have a double dose of sex (XX), they will obviously be females; however, since it takes a double dose of color-blindness (XX) to cause

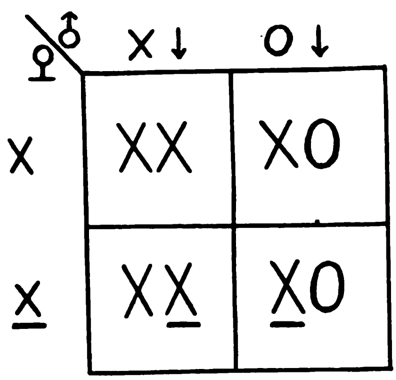

Fig. 119. When one of the carrier girls, produced from the mating indicated in Fig. 118, marries a normal man, half of her daughters will be normal and the other half carriers. One-half of her sons will be normal and the other half color-blind. It should be noted that the carrier sisters of the color-blind boys will contain in their cells as much of the color-blind factor as was possessed by the boys. However, since it requires a double-dose of color-blindness to produce a color-blind female and only a single dose to produce a color-blind male, the former will not, and the latter will, be color-blind.

them to be color-blind, they will be apparently normal girls. In other words, they are girls because they have a double dose of sex (XX) but *not* color-blind because they have only a single dose of that defect (X). Since the marked X shows that these girls carry the undesirable determiner for color-blindness in their germ cells they are "carriers" and will taint their children with this characteristic. The second and fourth squares represent the males. Since they received no sex determiner from the father and only one from the mother, as the figure shows, the boys are all normal and in no way tainted because they have no sex-chromosomes which contain the factor for color-blindness. Therefore, when considered from the standpoint of the union of the germ cells of the father and the mother, it is clearly seen that the mating of a normal woman and a color-blind man will result in the production of normal boys and "carrier" girls.

Case II. "Carrier" Marries a Normal Man (Fig. 119).—Should one of the girls ("Carriers") considered above (Case I) marry a normal man, an interesting group of children would

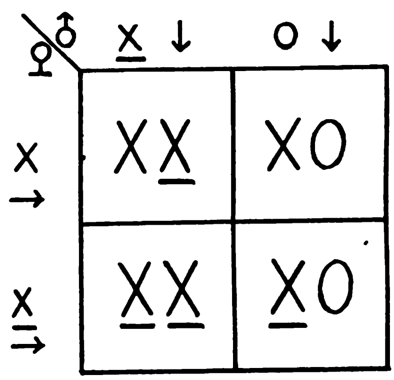

Fig. 120. A color-blind man marries a carrier woman and produces the following offspring: one-half of all sons and one-half of all daughters will be color-blind (since the former possess a double and the latter a single dose of the defect). The remaining daughters will be carriers and the remaining sons will be normal.

result. A reference to the figure (Fig. 119) will show that one-half of the girls (first square, XX) would be normal while the other half would be "carriers" (third square, $X\underline{X}$). One-half of the boys would be normal (second square, XO) and the other half would be color-blind (fourth square, $\underline{X}O$)—since only a single dose is necessary to produce color-blind boys.

Case III. Color-blind Man marries a "Carrier" Woman (Fig. 120).—Suppose now that this color-blind man ($\underline{X}O$, Case II) should marry a "carrier"; that is, a girl whose germ cells contained the determiner for color-blindness, equally as interesting a group of children would result. One-half of the girls

(Fig. 120) would receive an affected $\underline{X}$ from their father and a normal X from their mother and, thus, they would be "carriers" (first square, $X\underline{X}$). The other girls would receive an affected $\underline{X}$ from both parents; and, as this would be a double dose of the determiner, they would be color-blind (third square, $\underline{X}\underline{X}$). As one-half of the boys would receive no sex-chromosome from their father and, consequently, no determiner for color-blindness, and also an unaffected chromosome from their mother, they will be normal with respect to their sight (second square, XO). The other half of the boys will receive

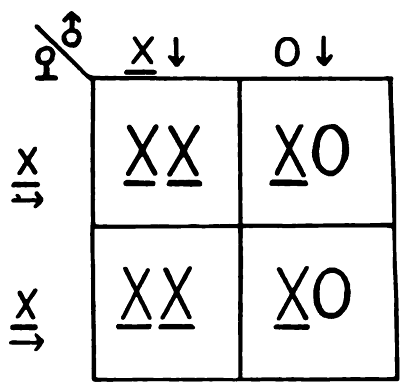

FIG. 121. When both parents are color-blind all the children will be color-blind.

an affected $\underline{X}$ from their mother and none from their father, and, as a result, they will be color-blind (fourth square, $\underline{X}$O).

Case IV. Color-blind Man Marries a Color-blind Woman (Fig. 121).—Should two individuals such as the woman represented by the third square in Case III ($\underline{X}\underline{X}$) and the man represented by the fourth square ($\underline{X}$O) marry, the figure (Fig. 121) which is constructed to show the nature of their progeny very clearly indicates that all such children will be color-blind. In the first square ($\underline{X}\underline{X}$) and the third square ($\underline{X}\underline{X}$), an affected sex-chromosome is brought in by both the father and the mother. As a result, the children will be color-blind girls because they have a double dose of both sex and the determiner for color-blindness. In the second square ($\underline{X}O$) and the fourth square ($\underline{X}O$) an affected sex-chromosome is received from the mother and none from the father. Since it requires only a single dose of sex to produce boys, and since it requires only a single dose of the determiner for color-blindness to produce that defect in boys, the children represented by these two squares will be color-blind boys.

Case V. Normal Man Marries a Color-blind Woman (Fig. 122).—If the father is normal and the mother color-blind, all

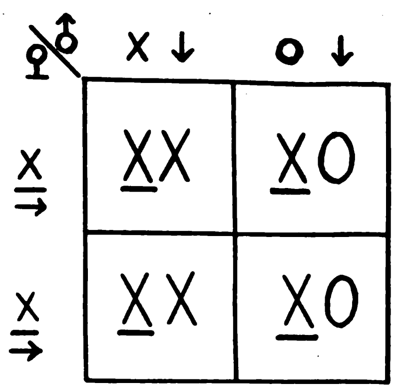

Fig. 122. A color-blind woman and a normal man will produce carrier daughters and color-blind sons.

the sons will be color-blind and all the daughters will be "carriers." This is true because all the children will receive a single dose of the determiner for color-blindness. Figure 122 is a representation of these conditions. The affected $\underline{X}$ of the mother meets the unaffected X of the father in the first and third squares. These squares ($\underline{X}X$), then, represent the "carrier" daughters. In the second and fourth squares, the affected $\underline{X}$ of the mother carries the only determiners for both sex and color-blindness, these children are color-blind boys.

From the facts presented in these figures (Figs. 118 to 122), we may conclude that: The children from a color-blind father and a normal mother will all be normal in appearance, but the girls will be "carriers"—capable of transmitting color-blindness to their own children (Case I). When the mother is a "carrier" and the father normal, one-half of the daughters will be normal and the other half will be "carriers," one-half of the sons will be normal and the other half color-blind (Case II). Should a man who is color-blind marry a "carrier" woman, one-half of the boys will be normal and one-half color-blind, while one-half of the girls will be color-blind and the other half "carriers." When both parents are color-blind all their children will have the same defect (Case IV). If the father is normal and the mother is color-blind, all of the sons will be color-blind and all of the daughters will be "carriers" (Case V).

CHAPTER XXVII

SUPPOSED INHERITANCE OF DISEASES

The Disease Germ—"Catching" Colds—Peary's Expedition—Epidemics—Contagious Diseases—Hereditary Induction—Tuberculosis—Prenatal Infection—"Inheritance" of Venereal Diseases—Gonorrhœa—Syphilis—Miscarriage—Danger to Innocents—Marriage Laws—Disadvantages of Children of Afflicted Parents.

"The highest duty, the one essential duty, is the perpetuation of the family life based upon the mutual love and respect of the one man and the one woman and upon their purpose to rear healthy and high-souled children."

—*Theodore Roosevelt.*

The Disease Germ.—The *germ theory of disease* within itself constitutes a *flat contradiction* of the idea that *diseases are transmitted by heredity.* When we say that we have "caught" a cold, we eliminate all possibility of its inheritance. This statement is, indeed, very true, for we do actually "catch" colds; we *do not* inherit them. This fact was conclusively established by the experiences of Peary's party while exploring the Arctic regions. Colds were unknown after they left their ships and began their march thru the snow and ice of the far north. They were warm, dry, and comfortable while on board ship, but after they left it they often slept with their clothing saturated with moisture even when the thermometer registered many degrees below zero. While on board the ship, they breathed the germ-laden dust which floated in the impure air of their close quarters, and, as a result, they frequently suffered from colds. When they penetrated into the far wastes of the Arctics, where no man had been before them to leave the germs which produce colds, they had no fear of taking cold.

Attention should be called to the fact that when two or three children in a school become infected with colds, a general epidemic usually breaks out and includes practically every child within its reach. While Principal of a certain high school, the author collected considerable data on this subject. At one time, school had been in session for more than three months without a single case of a cold being recorded when, on a certain Monday morning, one girl appeared in the study hall with a severe attack. At the end of three weeks, the records showed that fully ninety per cent of the student body and the faculty had suffered from the epidemic. Such examples as these prove that common colds and bronchitis are caused by disease germs which are taken into the system from external sources and not from impure germ plasms; that is, thru heredity. It is, therefore, within the power of man to reduce the millions of annual cases of such infection.

It seems to be universally accepted that such diseases as diphtheria, typhoid fever and smallpox are caused only by their respective typical germs and that they may be prevented by the proper precautionary measures; while, if they were capable of being inherited, they would be practically beyond human control.

Hereditary Induction.—While people in general consider such diseases as being purely contagious, the opposite view is often held with reference to tuberculosis. This is evinced in such popular expressions as: "I am not surprised that this man has consumption for his father died of it," or, "That child inherited tuberculosis from his parents." Let those who still hold the belief that this plague is handed down from father to son consider the fact that tuberculosis recurs in the same locality, and in the same house, year after year. The fact that this recurrence continues in the same houses, regardless of *the fact that the inhabitants change*, shows that the *houses are infected* rather than that the disease is inherited.

The more popular becomes this view, the more successful will be the attempts to sweep this great white plague from the face of the earth. The bacteria of tuberculosis kill almost 150,000 people each year, but the death rate is decreasing most remarkably since the germ theory of this disease has become so well known. The success or failure of the battle against this most dreaded disease depends upon the acceptance or rejection of the principle of disease transmission which is involved.

Even in this supposedly enlightened day, *there are thousands who question the real existence of disease.* If this backward movement continues, and should it grow, the "so-called" disease germs will play havoc with the human race within a very few generations. Is it not time for such non-progressive citizens to face about and consider *facts* and not *mere fancy* and, by so doing, assist in the solution of the present-day problems? What a strange mythical conception it is to claim that diseases are only a condition of the "mortal mind" caused by certain sins of the individual concerned! One faithful "practitioner" informed the author that the Spanish Influenza epidemic (1918-1919) was traceable to "mind" and "sin." Whereupon the informant was reminded that it was indeed deplorable that the adherents of this "faith" did not withhold their sinning and remain well so that they could care for their neighbors until they should recover from the disease.

In view of the facts regarding the transmission of tuberculosis, the question naturally arises as to the relation between the child and the infected parents; and also, regarding the tubercular child and the family which is free from this disease. It has been said that the child whose parents have died of the disease is put to no more disadvantage than if its parents had never been infected—assuming, of course, that the child had been left when quite young and reared under favorable conditions. This view, however, is too extreme if presented without modifications. It assumes that the prolonged suffering of the parents and consequent degeneration of the cells—

which thus poisons the whole system—has had no effect upon the germ cells. Since the germ cells are nourished thru the blood circulation the same as are the body cells, it is obvious that they receive the same poisoned food. Thus, they would be poorly nourished and otherwise injured. *It does not seem probable* that they would be normal under such adverse conditions. In fact, there seems to be no room to doubt that *hereditary induction* does take place under such circumstances.

It was noted in the last chapter that alcoholism was "inherited" even unto the third and fourth generations. Although this conclusion was reached as a result of certain experimentations with lower animals, it seems probable that the same principle of "induction" would apply in the case of man. It has been noted by some experimenters that certain mutilations of the spinal cords of guinea-pigs caused epilepsy which recurred in the offspring for two or three generations. Woltereck, who first suggested the term "induction" for this phenomenon, found that when a minute water flea (Daphnia) was exposed to certain conditions of low temperature, the after effect upon the offspring was noted for two generations. In all the cases investigated up to the present time, the normal condition has returned after a few generations. This shows that, although poisoned or otherwise affected and consequently modified, the germ cells have undergone only temporary changes. Thus, *hereditary induction is not a true type of heredity.* Is it not probable that the germ cells of a man or a woman who is in the last stages of a lingering type of pulmonary tuberculosis would be affected more vitally than those of a guinea-pig which had breathed air saturated with alcohol, or those of a water flea which had suffered certain inconveniences thru reduced temperature? Thru this process of reasoning, we would conclude that tubercular parents would have an *inductive* effect upon their children; that is, a child whose father died of tuberculosis would be *more likely to be defective* than it would had the father not been so afflicted. This defect, however, may or may not be susceptibility to the tuberculosis bacilli. The child is just as likely to be defective in some other way.

A certain fallacy should be noted in the above conclusion. In order that induction may be effective, the germ cells must suffer the temporary alteration before the one which is to form the future child is used in the process of fertilization. That is to say, the parent must have been seriously affected before the child was conceived; otherwise the germ cell would not have been altered, and, thus, the child would be normal. It is easily observed, therefore, that this type of "inheritance" is of minor consideration, for very few children are begotten after the parent has reached an advanced stage of the disease. The mother is often accused of being more responsible for the transmission of such diseases than the father—at least from the standpoint of *germinal induction*. This is not true. The father may leave progeny only a few days before he dies of lingering pulmonary tuberculosis which has poisoned his whole system to such an extent that every cell of his body has become completely saturated with the poisons and reduced almost to a state of "living death." In the case of a woman, this type of induction is less likely to occur as the ovum must be fertilized and *cease to be a part* of the mother almost nine months before the birth of the child. The mother might suffer from the disease the entire time and give birth to a child only a few hours before her death without affecting the child in the least so far as a change in the constitution of the germ cells is concerned. However, the baby might be a "weakling" on account of a lack of nutrition before birth, or it may "catch" the disease by being infected thru actual contact with the mother during or immediately following birth.

Much emphasis is sometimes placed upon pre-natal infection. It is shown in another chapter that the child, before birth, is nothing more than a parasite on the wall of the uterus of the mother—the circulation of the child being entirely distinct from that of the mother. The food, in solution, flows with the blood thru the capillaries of the mother to the placenta, and passes by osmosis to the capillaries which unite to form the umbilical artery, and thence to the child; the child floats in a liquid (amniotic fluid) which is sealed off from the maternal tissues. Under such protection, it would seem ***improbable*** that disease germs which do not have a particular affinity for the sex organs could cross the bridge from the mother to the child. Pearson has found that there is a marked correlation between tubercular parents and tubercular children, but ***there is very little evidence that the child is ever infected before birth.***

In addition to the inductive effect of poisoning the germ cells, many present-day writers are emphasizing a more direct method by which a diseased and otherwise injured mother might transmit subnormal conditions to her unborn child. It is claimed that the poisons which might be in the mother's system can be transferred to that of the child thru the process of osmosis which is continuous between the circulations of the two. Dr. F. J. Laase, associate surgeon of St. Mark's Hospital, New York City, has reported an interesting case which seems to touch upon this point. This case seems to show that a habit *acquired* by the mother was transmitted to her child. The mother was an opium addict and had been such for approximately two years. The child was born seemingly normal in all respects but was extremely restless from the moment of birth. Dr. Laase interpreted this condition to an opiate need due to an insufficient amount being taken by the mother shortly previous to confinement. The restlessness of the infant increased within a short space of time and it exhibited all the symptoms of a drug addict; its face became pinched and wan, it drew up its legs as if it had cramps, and it cried lustily. The pupils of its eyes became dilated, its chin trembled, and it finally showed signs of a complete collapse. No means could be found to cause a subsidence of these symptoms until a drop of paregoric was given, and then they disappeared in direct ratio to the amount of the drug administered. The mother did not desire to continue giving the child the opiate and delayed each dose as long as possible. The child developed the symptoms in varying degrees according to the length of time between administrations of the drug. The necessity for the use of the paregoric came to an end when lactation was brought about; the baby must have obtained its supply of the narcotic thru the milk of the mother. Before each period of nursing, the child would show a restlessness quite unlike that of any other normal child, but it would cease after its appetite was satisfied. The restlessness of the child increased *when the mother took the drug at longer intervals.* Very evidently the child must have acquired this need for a narcotic before birth. Such a condition could easily be brought about, as the drug could enter the embryonic circulation thru the placenta by osmosis and, thus, it would not be a truly inherited "acquired character."

"Inheritance" of Venereal Diseases.—The conclusion regarding the improbability of the prenatal transmission of tuberculosis and other diseases which do not directly attack the sex organs does not seem to hold true with the various venereal diseases. While it is improbable that the disease germs enter the mature sperm, or the egg, and cross over the hereditary bridge which spans the mechanism of fertilization, it does seem quite certain that the child may "catch" the disease from its mother many months before its birth. Since gonorrhœa, syphilis, and the like, have a special affinity for the sex organs, the germs seem to be much more likely to penetrate the embryonic membranes and thus affect the unborn child, than the contagious and infectious diseases of other types.

This prenatal infection is playing havoc with the human race. During the first stages of pregnancy, the normal tendency is for the uterine lining to expel the tiny parasite, the child, from its walls. This tendency is so great that miscarriage seems to be the normal process under such circumstances. If the uterine walls and even the tiny embryo are infected, how much greater must be the chance for miscarriage.

It may be a cruel thought, but it occurs to the author that the ease by which miscarriage is incited is a great factor in favor of both social and evolutionary progress. Were it not for this simple process, the countless millions of feeble-minded, epileptic, deformed, and insane children, which are brought without welcome into a miserable existence, would be many times multiplied. Sexual sin has become so prevalent that the most innocent are always in immediate danger lest they come into contact with the germs that the guilty and the vile are constantly scattering throughout the world. So readily infectious are these diseases that the innocent might fall victim by the use of an unclean towel, public toilet, public drinking cup, or by any other simple means. One young man, whose innocence never would be questioned, was reported to have fallen a victim to syphilis. After much investigation, his family physician established the fact that he was infected when accidentally struck in the corner of the mouth by the end of a whip which a "rotten" hackman had been in the habit of chewing. Unquestionably, a large percentage of the "dead at birth" are traceable directly to prenatal infection. The same might be said of many early deaths, as well as many cases of feeble-mindedness, insanity, granulated sore eyes, and various defects of the sense organs.

Although there is no question but that the total of "inheritance" of the various venereal diseases can be summed up in the two words *prenatal infection*, we are in grave danger of attributing too many cases to this one cause. It must be remembered that the child comes into direct contact with the sex organs in the process of being born, thus rendering it practically impossible for an infected mother to give birth to a child without infecting it. The eyes are especially susceptible under these circumstances. If the child escapes the disease until after birth, it is still in danger of being infected during early childhood. In all probability, the infection of children from towels, handkerchiefs, or other toilet articles used by a careless mother, father, or other member of the family, will account for many instances of supposed prenatal infection; this throws some of the responsibility upon the other members of the family rather than forcing the mother to bear the whole burden. The author does not agree with the popular custom of thrusting the entire burden of sexual impurity upon the male members of the household, although, of course, it must be remembered that many innocent women are infected by their husbands. Later, they give birth to sore-eyed, syphilitic children and are forced to endure the insulting remarks of the public to the effect that they had syphilis and gave it to their children before they were born. For many years, women and children have been the victims of various diseases. Sometimes, and indeed more often, they were entirely ignorant of the fact that they were afflicted. Young wives and mothers who had been healthy have been severely mutilated by surgical operations; some of them have lost their health entirely, some have become incapable of bearing children, and still others have died as a result of this terrible disease. Many babies have been born hopelessly defective, others have been blinded a few hours after birth, and others have died, solely because of their parents' sins.

Downing summarized the influences which venereal diseases have upon society as follows: "It is probably safe to say that these diseases are the cause of more misery than all the other diseases put together. It is difficult to make a cautious statement of their results. Even conservative physicians in writing of their effects are prone to make assertions that read like those of the alarmist. They are undoubtedly spread chiefly by sexual impurity. So appalling are their results that many extreme measures have been advocated to check their havoc. Some states now prescribe that before a marriage can be legally performed both the contracting parties must furnish to the proper authorities a certificate that they are free from venereal diseases. Some states, recognizing the correlation between these diseases and crime, insanity, imbecility, and pauperism, provide for the segregation of such people and their confinement under conditions which will make the bearing of children

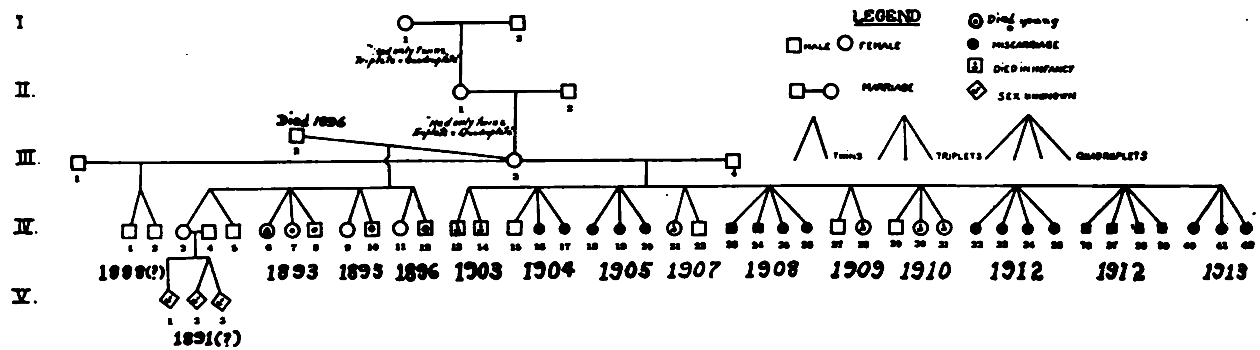

Fig. 123. Over-production among the inferior. (From Davenport, *Journal of Heredity*, November, 1919—dates of births added from Davenport's text.) The above chart shows that a certain defective woman of Cleveland has been married three times and produced forty-one offspring, eighteen males and twenty-three females, among which there were no single births. Of these forty-one children, only ten reached the teen age, typical of the over-productiveness of those with "mental limitations"; such people, being governed by instinct rather than reason, produce large numbers of abnormal children, the most of which are dead at birth, die in early childhood, or perchance are thrown upon the mercies of the public. As indicated by the chart, there were born to this woman (3) by her first husband, one set of twins. After the death of this man she married again and produced three sets of twins and one set of triplets. Of these nine children born during five years, five died young. The offspring by the third husband showed even a lower percentage of normality. Three sets of twins, four sets of triplets, and three sets of quadruplets, gave a total of twenty-nine children in ten years—an average of almost three per year. Of these twenty-nine children, only four seemed to have reached maturity.

impossible. In some states it is incumbent upon the authorities in charge of persons in insane asylums, penitentiaries, and institutions for the feeble-minded to sterilize such as are adjudged to be hopeless cases. But probably the most effective method of dealing with the situation is to bring to young people a realization of the prevalence of such diseases, even among men of the better social classes."

It was suggested above that miscarriage, especially when due to venereal diseases and other abnormalities, might be classed as one of the vital factors which promote evolutionary progress (Fig. 123). This principle might be applied to the lower animals as well as to man in whom natural selection and survival of the fittest play their part even before birth. The abnormal—the "unfit"—are aborted rather than being permitted to be born and later leave a race of unfit individuals. While thinking of the lower animals, this principle does not excite any particular grief. It does seem deplorable, however, that Nature must give the emergency call to two of her most faithful servants, "struggle for existence," and "survival of the fittest," to redeem man from the cursed sins of his own making. The most pitiful fact associated with the elimination of the unfit by miscarriage is that the woman is called upon to pay the whole price in suffering.

One does not realize to what extent "born dead" is a relief to human society until a study is made of certain families permeated with insanity, feeble-mindedness, epilepsy, alcoholism, and sexuality. The Jukes and Kallikak families are examples of such which will be considered later. These cases clearly show that with many, the bringing into the world of children is nothing more than a blind obeying of the dictates of an uncontrolled brutal passion. The only reason more children are not produced is because the period of pregnancy is nine months rather than twenty-two days as is the case of certain mice. What a blessing it would be to human society could some scientist discover a method of extending this period, in the case of the class of people cited above, to nearly two years, as in the case of the elephant. Then, the number of the unfit would be materially reduced.

The above illustrations and discussions show that it is impossible for disease germs to be inherited thru the germ plasm and also suggest some of the consequences of prenatal infection as well as induction. So far as actually inheriting the germ itself is concerned, the child of the diseased parent is no more handicapped than if the disease were unknown. However, the children of parents infected with tuberculosis or other prolonged diseases—sexual diseases excepted—suffer from at least four standpoints; namely: (1) Induction, (2) Inheritance of a weak constitution, (3) Insufficient nutrition and perhaps poisoning before birth, and (4) Living in an atmosphere which is saturated with germs. Therefore, under few conditions is it correct to say that the child of a diseased or alcoholic family has an equal chance with those from a normal home. It is fortunate that his success or failure lies largely in his own hands. With proper hygienic precautions, he may be able to resist the disease germs even though he may have inherited a low resisting power. With the child from a family of alcoholics, he may, by a determination born of an iron will, resist the temptation and by proper conduct, live above his social environment.

The young men or young women, knowing as they should the facts regarding the sexual diseases, should have, with rare exceptions, the power and determination to evade them. Is it not time, then, for the progressive young people of America to awaken to their responsibilities and lend a hand in the making of a purer race?

CHAPTER XXVIII

PRENATAL CULTURE AS RELATED TO HUMAN PROGRESS

Introduction—Totemism as Probable Basis for Present Antiquated Views—Obsolete Views of Civilized Man—Examples of "Birthmarks"—Facts about the Birthmarks—Cause of Birthmarks—Relation between the Embryo and the Mother—Fertilization and Implantation of the Ovum—Conclusion.

"I know not what may be the cost to both of us to rid me of that fatal birthmark . . . which was laid upon me before I came into the world. . . . Life is a burden which I would fling down with joy. . . . Either remove this dreadful hand or take my wretched life."

—*Georgiana in "The Birthmark,"*
Taken From
"MOSSES FROM AN OLD MANSE"
by Hawthorne.

Introduction.—From the time of the nomadic tribes of distant prehistoric periods to the second decade of the Twentieth Century, even in many of the supposedly enlightened communities, fantastic ideas regarding prenatal influences have remained practically unchanged. The most common of these influences have found expression in the prevalent explanations for the so-called birthmarks. During this expanse of time, millions of expectant mothers have undergone untold mental agonies, extreme physical inconveniences, and, indeed, torture on account of the popular belief that some accidental occurrences might affect their own mental conditions, and thus cause their children to be born defective in some physical or mental characteristic (Fig. 124). Many children have been ushered

Fig. 124. The picture at the top of the page shows a typical dwarf in company with a deaf-mute who possesses an unusually large goiter. (Bottom) Eva, Agnes, Maude. Were these children "birthmarked, or was their pitiful condition caused by alcoholism, venereal diseases, or heredity? It is the function of the Science of Eugenics to search the truth in such cases. The American people are spending millions of dollars every year in caring for the defectives, but comparatively nothing is being invested in "cause and prevention."

into this world as weak, degenerate beings unable to cope with the vicissitudes of life solely because of improper prenatal care—the mothers failing to take proper exercise and wholesome nourishment for fear that some unpleasant experience connected therewith would blight the life of their children-to-be.

The present popular notion of birthmarks was so prevalent in the "Old Testament" days that the conception was extended into the animal world. If a certain type of cattle was desired, the cows were forced to look upon certain objects, and thus the calves would be "birthmarked" in some specific manner. As a result of certain agreements between Jacob and Laban (Gen. 30), the former was entitled to all the striped and spotted cattle which might be born, the latter taking all that should be of solid color. In the absence of Laban, Jacob devised the following scheme by which his share of the cattle might become the greater.

"And Jacob took him rods of green poplar, and of the hazel and chestnut tree; and pilled white strakes in them, and made the white appear which was in the rods. And he set the rods which he had pilled before the flocks in the gutters in the watering troughs when the flocks came to drink, that they should conceive when they came to drink. And the flocks conceived before the rods, and brought forth cattle ring straked, speckled, and spotted."

Although Jacob, by this method, soon found himself the owner of a large percentage of the herd, he was not as yet satisfied but proceeded to mark the best for himself and leave the "scrubs" for his partner.

"And it came to pass whensoever the stronger cattle did conceive that Jacob laid the rods before the eyes of the cattle in the gutters, that they might conceive among the rods. *But when the cattle were feeble, he put them not in:* so the feebler were Laban's and the stronger Jacob's."

Totemism as Probable Basis for Present Antiquated Views.—The fact that the modern conception of the various prenatal influences was handed down from the earliest tribes of prehistoric times, is demonstrated by a study of similar ideas held by the semi-civilized races which are still in existence. Practically all such tribes are strong adherents to the principle of totemism, a type of superstition which bears a close relationship to the subject under consideration. Indeed, it can be said with a great degree of assurance that many of the present-day erroneous beliefs are derived from primitive customs of savage races. According to Frazer, "totemism is an intimate relation which is supposed to exist between a group of kindred people on the one side and a species of natural or artificial objects on the other side, which objects are called the totems of the human group." In like manner, each individual of the group has his own specific totem. Usually the person took the name of his totem for his own, such as "Crab," "Deer," "Sitting Bull," etc.

These people, not being able to understand the origin and early development of the unborn child, conceived the idea of the child being a spirit with which certain women were endowed. Since the child was not considered to be in existence until the mother became conscious of its presence—perhaps by the characteristic sensation produced by the child's first movements—a direct relation was held to exist between this physical realization and the visual images which the mother may have had at that moment; that is, the cause of the supposed spontaneous appearance of the child was attributed to the material something which perchance attracted the attention of the mother at the crucial time. As Frazer says: "It might be a kangaroo that hopped before her and disappeared in a thicket; it might be a gay butterfly flitting past in the sunshine with the metallic brilliancy of its glittering wings." Regardless of the object that the mother saw at this particular psychological moment, the child would bear, when born, a direct resemblance to the thing, whatever it may be. In many cases, he would also take his name from it. Often this resemblance would find expression in certain markings on the child's body—birthmarks.

Obsolete Views of Civilized Man.—Although civilized man no longer adheres to the old principles of totemism as such, he still looks with favor upon some of the antiquated views handed down as a legacy by this primitive creed. All thru medieval and recent history and literature we find examples of the most ridiculous types of birthmarks which show that these views have been supported continuously from the earliest ages of "intelligent" man. In the trial (1743-45) to ascertain the legal heir to the Annesley title and estate, the vital question to be decided was whether the claimant was the son of Lord and Lady Altham or the son of their kitchen wench, Joan Laundy. During the course of the trial, one witness claimed to have conclusive proof that the child was the natural son of the kitchen wench rather than that of Lady Altham. The witness stated that she was present when the cook, quarreling with Joan, struck her with a hare which she was preparing for the oven, and, as she did so, cried out, "I will mark your brat for you!" According to the witness, the child, when born, bore the mark of the hare. Again (1746) we find that Lady Cromarty's baby bore the mark of an axe because her mind had been so disturbed over the probability of her husband's being executed by Prince Charles.

One might readily surmise that the present notion regarding prenatal culture was prevalent in Hawthorne's time, since he pictures Georgiana (in *Mosses from an Old Manse*) as having the mark of a hand on her cheek. This mark, though greatly admired in her youth, came to be a "symbol of imperfection," especially to her husband, Aylmer. After Aylmer speaks out in his dreams, "It is in her heart now; we must have it out," Georgiana expressed her feeling thus: "I know not what may be the cost to both of us to rid me of this fatal birthmark. Perhaps its removal may cause careless deformity. Or it may be the stain goes as deep as life itself. Again, do we know that there is a possibility, on any terms, of unclasping the firm grip of this little hand *which was laid upon me before I came into the world?* . . . Life is a burden which I would fling down with joy. Either remove this dreadful hand or take my wretched life." After many vain attempts, Aylmer was able, by giving Georgiana a draught of a sparkling liquid which he had prepared, to cause the crimson mark to fade; but, as the mysterious hand faded, so passed the life of its possessor.

Lucy, one of the characters in *The Ordeal of Richard Feverel*, was a prospective mother who desired her unborn child to become a great historian. In order to bring about this desire for the child, she had a gentleman come to her home each evening and read and discuss history with her.

Numerous quotations such as "So many spots like nævus [birthmark] our Venus soil" from Dryden's *Death of Lord Hastings;* "It reappears once more as a birthmark on the forehead," from Longfellow's *Golden Legend II;* "The blemish that will never be forgot," and "Worse than a slavish wipe or birth hour's blot," from Shakespeare's *Rape of Lucrece*, are further proofs that the greatest of human minds have been steeped in this yet prevalent type of ignorance.

The almost universal prevalence at the present day of an erroneous belief in various prenatal influences will be demonstrated by questioning the mothers of nearly any community. As a result of such investigations, hundreds of "authentic" cases have been recorded. The "so-called" birthmarks tabulated below together with their attributed causes were narrated as "facts" by the members of one class in Heredity and Evolution—some of them being exemplified in the students themselves. They are typical of the hundreds of dangers which the average mother thinks she must evade in order that she may produce a perfect child.

Birthmark	*Attributed Cause*
1. Girl had half a strawberry on knee. Seeds visible.	1. Before birth of baby, mother craved strawberries and sent a child to get some. Child brought one and demanded half. Mother cut berry on knee.
2. Snake coiled around man's leg, tail at ankle and head at thigh.	2. Short time before birth of child, mother stepped into rattler's den and one coiled around her limb.
3. Blackberry on thumb.	3. Month before giving birth to baby, mother was invited out to dinner where blackberries were served. Did not get enough at the table to satisfy her, so while eating some afterwards she dropped one on her thumb.
4. Boy had patch of hog's bristle on leg.	4. Mother chased by hog before boy's birth.
5. Woman with raspberry on back of neck. In raspberry season clearer with white sores resembling seeds.	5. Children broke a jar of freshly canned raspberries. Mother-to-be became angry and scratched the back of her neck.
6. Young lady with brown spot resembling beefsteak on neck.	6. Mother-to-be craved beefsteak and was unable to get it.
7. "Mouse's skin" on shoulder.	7. Mother frightened by a mouse while child was in embryonic stage.
8. "Mashed strawberries" on neck.	8. Mother saw mashed strawberries on a paper blowing across the street, and threw hand on neck with exclamation.
9. "Cucumber" at waist line.	9. Mother put hands on hips while having a craving for cucumbers.

Birthmark	*Attributed Cause*
10. Child had "wings" on shoulder.	10. While pregnant, mother cared for a crippled hen.
11. Girl's feet turned in and hands drawn back against wrists.	11. A few days before child's birth, mother doctored a dog that had its feet cut off.
12. "Snake" on head.	12. Mother saw husband kill snake which fought. She put her hands on her head.
13. Spot on jaw.	13. Mother saw father shot in head night before birth of child.
14. Red spot covering cheek, part of nose, and chin.	14. Pregnant mother poured grease in fire. It blazed up and she put hand to face.
15. "Piece of cake" above knee of child.	15. Mother, while complimenting some lady on her cake-making, slapped herself on this spot.
16. "Head of horned cow" below shoulder blade.	16. Mother chased by cow a few months before child's birth.
17. Red spots on arm.	17. Mother took care of a child that had been burned and her child had the same number of spots.
18. Mark on each hip resembling coffin.	18. Mother looked at son's corpse which had been brought home in a coffin.
19. "Bird" in flight on throat.	19. Cat killed pet bird. Pregnant mother saw it and put hand to throat.
20. Strip of yellow "dog's hair" on hip.	20. Mother saw dog fight and rubbed hand on hip.
21. One hand with mere buds for fingers.	21. Mother saw boy with fingers shot off.
22. Side of head, body, and limbs purple.	22. Drunken father threw wine on side of pregnant mother.

Birthmark	*Attributed Cause*
23. Individual thru life afraid if even a finger is pointed toward him.	23. His father shot at his mother and grazed her cheek, frightening her.
24. Club-footed and hands off above wrists.	24. Mother had made fun of club-footed girl whose hands had been amputated.
25. Child born with insane look and eyes crossed.	25. Mother helped husband as door keeper in asylum. She encountered an insane man, and he frightened her with an awful stare.
26. Lady born with a death-like pallor.	26. Mother saw corpse of her father.
27. Child disliked onions and punished its enemies by rubbing onions in face and eyes.	27. Mother ate too many onions before the birth of the child.
28. Child's face marked with long red streaks.	28. Mother, who was trained nurse, assisted in an operation.
29. Child with ten fingers and two thumbs.	29. Mother witnessed sleight-of-hand performance.
30. Child with staring eyes, queerly shaped hand, and one foot which was dark on bottom.	30. Expectant mother, during early development of embryo, saw, within a week, a cub bear, a frightened turtle with bulging eyes, and an Indian with one foot off.
31. Girl with double joints.	31. Mother saw a dog with front feet cut, making it look as if it had double joints.
32. Child born with sore eyes, which continued weak throughout life.	32. Mother petted family dog, which had sore eyes.
33. Woman afraid of worms.	33. Husband had frightened mother with worms.
34. Dislike for bean soup.	34. Mother ate too much during pregnancy.

Birthmark	*Attributed Cause*
35. Musical talent.	35. Mother studied music during pregnancy.
36. Fondness for reading.	36. Mother spent much time during pregnancy in reading.
37. Child nervous.	37. Mother saw husband killed in runaway.
38. "Slice of ham" on boy's thigh.	38. Ham fell from its place on nail to floor. Mother frightened and put hand on hip.
39. One-armed child.	39. Pregnant mother excited by the sight of one-armed man.
40. Birth of *girl.*	40. Mother *wished* so strongly for a girl that it caused the child to be a girl.
41. Birth of *boy.*	41. Mother thought too much about the war and the boys "over there."
42. Man who reels like a drunkard when he walks.	42. Mother was frightened by a drunken man before her child was born.
43. Child cries all the time.	43. Mother saw her son run over by a wagon and his legs crushed. She grieved and cried so much that when the child was born it cried all the time.
44. Woman with mouse, tail, and four legs on her arm.	44. Mother was frightened by a mouse crawling up her sleeve.

Facts about Birthmarks.—It will be noted from the foregoing records that many variations, and indeed, some normal conditions might be considered as a direct result of certain prenatal happenings, and that a cause which satisfies the populace is attributed to each. The absurdity of the popular notion regarding the causes of such variations is especially apparent when a large number are considered. However, if one case is considered alone—as a mulberry on a child's back—no particular mystery is attached thereto.

Birthmarks, sometimes spoken of as "mother's marks" or "birth-hour blots," are known to the physician as *nævi* (Lat., a spot, mole, or wart). They include any unusual markings of the skin. The ordinary form of *nævus*, known as *nævus vasculosus*, may be present at birth or may appear immediately thereafter. These markings usually present themselves as red stains ("port-wine stains," "fire marks," "wine stains," etc.) of very irregular contour and usually somewhat elevated above the surrounding surface of the skin. They may be mere spots, as a common mole; or they may cover the side of the face, neck, and even one shoulder. Since a nævus ("birthmark") is a kind of vascular tumor of connective tissue containing blood in its spongy meshes, its color will vary from light brown to purple—depending upon the amount of blood in the meshes and also upon the amount of skin pigmentation. The more common "fire marks" are caused by excessive dilation of the superficial skin capillaries. Since the color of these markings is more or less in proportion to the amount of blood contained in the abnormal spongy and fibrous surface tissues, it is obvious that the color will change when the amount of blood contained varies, as in the case when the person is under excitement such as crying, laughing, or blushing, or when in fear, or anger. The author has had the opportunity to make a close study of this special peculiarity of so-called birthmarks, since his own daughter has such a mark on the back of her neck. Although the marking is ordinarily practically invisible, an outburst of tears or laughter will bring it into prominence. Upon these facts are based the erroneous beliefs that some such marks are more conspicuous during certain seasons. There is no question, for example, but that the strawberry on the knee of the girl mentioned in case eight above, or the cucumber in case nine, will change color during strawberry or cucumber season—particularly if the person is in the field and becomes very warm, thus causing a vascular dilation of the surface blood vessels and allowing a large amount of blood to come to the skin.

The capillaries of the skin and the underlying tissues are, in many *nævi*, so greatly enlarged that they connect with each other and also with the outer surface, thus producing abundant secretions whose odors are sometimes very disagreeable. Reynolds (1888) reported to the American Medical Association an interesting case of a ten year old boy who had a dark purple nævus on the left thigh and hip, almost encircling the limb. The constant discharge from this "birthmark" was so profuse and so offensive that the lad was deemed to be unfit to be in company with other children. A similar case has come to the personal knowledge of the author. A lady teacher bore such a mark on her cheek which discharged a bloody secretion at intervals. The bleeding continued for several hours and in sufficient quantity to saturate a number of handkerchiefs. The fact that excitement produced the usual marked effect upon this elevated congenital varicose nævus was demonstrated when the teacher became angry and attempted to punish a mischievous boy. As her face flushed with anger, the "mother's mark" began to bleed so profusely that the task of punishing the little urchin had to be temporarily abandoned.

Cause of Birthmarks.—As has been shown by the foregoing examples, birthmarks are popularly thought to be due to certain prenatal impressions in the way of a longing, a fright, or an aversion to particular objects or things; or, as shown by the examples, any accident or occurrence which in any way affects the mental condition of the mother during pregnancy may cause physical disarrangement of certain parts of the child's body. Although cases are often cited which seem to possess a considerable degree of plausibility, unquestionably the principle of coincidence is the basis for the true explanation. The experiences of the mother are so varied during the nine months preceding the birth of the child, and the causes of each type of marking so numerous, that any mother can readily think of a cause that will serve as a more or less rational explanation for any abnormality which might appear. Take, for example, case eight in which a young lady was marked by a "mashed strawberry" on the neck. *Unquestionably the mother could have thought of a dozen causes* which would have served even *better* than the absurd one she gave.

Relation between the Embryo and the Mother.—The prevalent notion regarding prenatal influences is founded upon the erroneous idea that the child, before birth, is part of the mother almost in the same sense that the organs of her body are part of her. To one who understands the relation between the mother and her unborn child, the idea of prenatal influence is ridiculously absurd. Who would dare to suggest that the thoughts of any individual would amputate a limb or affect the nervous mechanism of a tick which was feeding upon his or her arm? Would this not be plausible if the mother's thoughts and actions render corresponding effects upon the unborn child? The two cases are more or less parallel, for the embryo is nothing more than a parasite on the walls of the mother's uterus. In other words, the tick is an *external* parasite while the child is an *internal* parasite. They both draw their nutrition from the host.

Since this internal parasitic existence is so different from the free living habit, it is necessary that special organs be developed by which the processes of anabolism and katabolism may be carried on. A brief reference to these embryonic organs, and a consideration of the relation between the mother and the unborn child should suffice to show that prenatal influences are impossible *except* from the standpoint of *nutrition* and *direct mechanical injury.*

Fertilization and Implantation of the Ovum (Fig. 125).—Since the subject of fertilization was considered in connection with the history of the chromosomes, it remains now to show how the fertilized egg attaches itself in a parasitic manner to the wall of the uterus. After the fertilized ovum undergoes a number of divisions, it burrows into the spongy uterine mucosa, causing a breaking down of the neighboring tissues and permitting the blood plasma to extravasate. This process is conducive to the growing up of the uterine tissues around the embedded human parasite. It will now be noted that the tiny parasitic embryo is protected on one side by the inner layers of the uterine membrane (the future *decidua basalis*, B, Fig. 125) and on the other by a thin layer of the uterine mucosa (the future *decidua capsularis*, C) which by continued stretching remains as the protecting membrane for the embryo until about the close of the fifth month, when this membrane becomes so extended that it comes into contact with the lower walls of

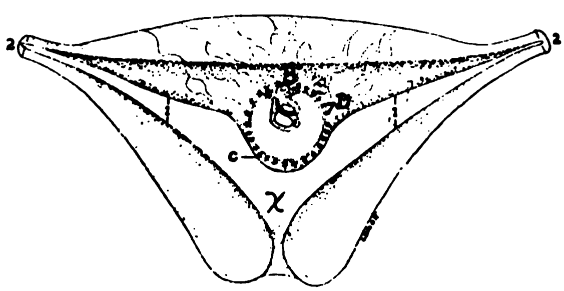

FIG. 125. Section thru uterus with embryo embedded in uterine mucosa. B. Decidua basalis. C. Decidua capsularis. D. Chorionic villi. X. Uterine cavity. 1. Decidua vera. 2. Fallopian tubes.

the uterus (the *decidua vera*, Fig. 126), thus obliterating the entire uterine cavity (X, Fig. 125).

As is the case with many parasites, root-like projections (chorionic villi, D, Fig. 125) grow out from all sides in order to absorb nourishment from the liquid of the surrounding space. Many of these villi continue to grow until they cross this space and begin to penetrate the tissues of the uterus. Since the greatest supply of nourishment is obtained from the inner layers (*decidua basalis*, B, Figs. 125 and 126), the rootlets in this vicinity undergo a very rapid growth, while those on the opposite side—being unable to obtain sufficient nourishment—eventually disintegrate. The embryo is now completely surrounded by a thin, capsule-like membrane (C, Fig. 126, *decidua capsularis*) and is connected on one side to the uterine wall by fixation villi (B, Fig. 126).

As the embryo enlarges and requires more nourishment, these villi continue to grow and erode the substance of the decidua basalis, and thus gain a greater absorbing surface. This organ, which forms the connection between the mother and the embryo, and which is vital to the nutritive, respiratory, and excretory functions of the embryo, is called the placenta.

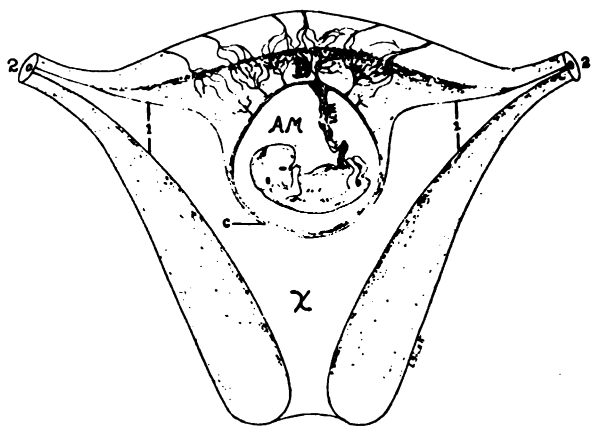

FIG. 126. Diagrammatic section thru pregnant uterus. B. Decidua basalis. C. Decidua capsularis. D. Chorionic basalis. X. Uterine cavity. Am. Amnionic cavity. Um. Umbilical cord. 1. Decidua vera. 2. Fallopian tubes.

Since this connection is more or less insecure, the splitting of the placenta thru the regions of the intervillous space is quite common. In this case the embryo, being released from the walls of the uterus, is free to be discharged. This abnormal occurrence is spoken of in the human race as *miscarriage*, and in the other mammals as *abortion*. Various diseased conditions of the placenta might be the cause of this mishap. With cattle, a certain type of abortion has been found to be contagious, being caused by a typical germ known as *bacillus abortive equinno*, "slip-bug." These germs infect the placenta, destroy it, and the embryo slips out, seemingly with but little harm to the mother.

It should be concluded from the above consideration that the blood of the unborn child receives nourishment from the maternal blood by *osmosis* thru the villous capillaries—*the two blood streams at no time coming into direct communication.* It is further important, from the standpoint of the present line of thought, to call attention to the fact that the cavity (AM, Fig. 126) which has formed around the embryo is filled with a liquid (*liquor amnii*). The embryo is now suspended by the umbilical cord (UM) and floating freely in this fluid. The umbilical cord connects the embryo with the placenta and is the sole avenue of nourishment. The liquor amnii varies considerably in amount at different times and with different cases. Under normal conditions, however, it seldom exceeds three pints—the greatest quantity appearing about the latter part of the eighth month. On the other hand, abnormal conditions may arise when the amount would decrease to such an extent that the embryonic membrane may come into contact with the embryo itself, and, *by certain irritations, or even adhesions, produce various embryonic scars ("birthmarks") on the unborn child.* McMurrich has said: "*Occasionally, also, bands of fibrous character traverse the amniotic cavity, and, tightening upon the embryo during its growth, may produce various malformations, such as scars, splitting of the eyelids or lips, or even amputation of a limb.*"

To the thoughtful reader, these simple facts should suffice to explain the cause of the ordinary so-called "birthmarks." However, many more technical malformations may occur. It must be remembered that the child was once nothing more than a mass of protoplasm, seemingly no more organized than a globule of jelly. From this homogeneous mass must come within only a few days the rudiments of the arms, the legs, the skin, the eyes, the ears, and various internal organs. Who would expect even Nature herself to formulate such intricate systems and organs from so small a beginning without a mishap? Is it not true that the absolutely perfect child is the extreme exception and that scars, blemishes, and various other markings are the rule? While the blood system is forming, many opportunities are presented for irregular pigmentation and the formation of moles and other types of blemishes.

Conclusion.—The foregoing considerations should not only establish the fact that the ordinary "birthmarks" in the form of physical defects are absurd scientific impossibilities, but that the whole category of prenatal influences are in like manner beyond the scope of scientific possibility. In view of the non-relation between mother and child and the absence of any form of nerve connection, how are the masses to support their argument that the child is to be moulded into a poet, a musician, a novelist, or an athlete, according to the life of the mother during pregnancy? Is it not strange that such statements as the following may still be read in American journals and recent books?

"Society has long ignored the power of prenatal influence."

"Post-natal has a great deal of influence in the moulding of the child's character, but postnatal is not to be compared with the influence of prenatal."

"The law whereby latent physical, mental, and moral characteristics of the parents—particularly those that are most active for some time prior to the initial of life, at the time of conception, and in the mother during gestation—are transmitted to the offspring."

"If a mother would transmit her special talents, she must exercise them during gestation."

"The brain is most easily moulded during embryonic development. When the brain areas are forming it is possible for the mother by assiduous exercise of mental powers to greatly modify the hereditary tendencies and to improve the mental tendencies and mentality of her child."

"By systematic methods parents may mould the tendencies of offspring before birth."

"It is during the prenatal period of a life that education, home influence, and the grace of God do their most effectual work in the formation of character."

One of the most ardent believers in prenatal culture dedicated his book as follows: "To my Father and Mother who, by their Religious Devotion *during my Prenatal Development* made the Desire to follow Christ in a Labor of Love for the Good of Mankind the Ruling Passion of my life, This Book is affectionately Dedicated." (*Heredity and Prenatal Culture*—Riddel.

To the reader who has fully perceived the relationship between mother and child as presented in these pages, the above quotations are quite absurd. If "it is during the prenatal period of a life that education, home influence, and the Grace of God do their most effectual work in the formation of character," then those who are deficient in any of these characteristics must ask their mothers to be totally responsible for such failures as may occur in life. What a strange character it would be who believed that the "special talents" of the mother could be transmitted from her brain to the uterine tissues *without a single nerve connection*, thence along the umbilical cord into the abdomen of the child and then into its brain!

How simple the whole process of race development would be if it were "possible for the mother by assiduous exercise of mental powers to greatly modify the hereditary tendencies and to improve the mental tendencies and the mentality of her child." How soothing this theory should be to the daughter of the author, since the authorities of one of the leading Universities conferred a degree upon her mother only five months before she was born. Discouraging as it may seem, my dear child, you must burn the "midnight oil" the same as do some of your classmates whose mothers were deprived of even a common school education! Were this theory a fact, every mother could choose the career for her child before its birth—she could look at beautiful pictures and produce a fairy princess; in brief, she could at her will present to the world a saint or a devil! Do observations of the *facts* substantiate these absurd assumptions? How would it be possible for a "beautiful thought" to upset the germ cell mechanism and thus cause the unborn child to be beautiful?

CHAPTER XXIX

INDIVIDUAL CONDUCT AS RELATED TO RACIAL DEVELOPMENT

Simplicity of Racial Development thru the Inheritance of Acquired Characteristics—Vitality of the Subject—Individual vs. Race—Triangle of Life—Pangenesis, Continuity of the Germ Plasm, and Modified Pangenesis—Use and Disuse—Environment, Adaptation and Natural Selection—Variation, Prodigality of Nature, Mutation, Amphimixis, and Hybridization—Induction—Mutilations—Supposed Inheritance of Acquired Characters—Germ Distinct from Soma—Experimental Proof—No Promiscuous Handing Down of Acquirements.

"A right answer to the question whether acquired characters are or are not inherited underlies right beliefs, not only in Biology and Psychology, but also in Education, Ethics, and Politics."

—Herbert Spencer.

"I will speak what I believe to-day, even if it contradicts everything that I said yesterday."

—Gladstone.

The relation between the every-day experiences of the individual and the evolution of the race is or should be more than a technical problem to be considered only by the trained biologists. Whether or not these daily experiences which so materially affect the individual are transmitted to posterity should be a live question for us all. What person would not be pleased to devote some thought to a consideration of whether the personal accumulations of a lifetime are capable of being handed down to his children? While considering whether or not such *acquired characters* are transmissible to the next generation, the eminent Herbert Spencer said, "A grave responsibility rests on the biologists in respect to the general question, since wrong answers lead, among the other effects, to wrong belief about social affairs and to disastrous social actions."

The breeder's success depends not on the improvement of the animals or plants which he now possesses, but on the improvement of the race or breed. Is the breeder of hogs, for example, to obtain a race of fat porkers solely by seeing that all his hogs are well fed? In brief, what effect will the acquirements of the parents have upon the next generation? It should be clear that such a problem is directly related to the theory of organic evolution. *If the individual actions and acquirements can render a direct effect upon the race, then man can mould evolution at his will.* The moulding of any race of beings, be it what it may, would be a very simple process should all acquirements be capable of transmission. Man could weed out those individuals who do not present acquirements suitable to his purpose, and thus perpetuate those desirable individuals who would produce the ideal race. The world is crowded with well-meaning people who wish to improve the race, but who, in their zeal, wholly overlook the germ plasm. They are adherents to the old belief that should they be able to change the somatoplasm in the desired direction, some unaccountable mechanism will perpetuate the acquirement into the next generation.

The characters of all individuals will fall under two heads. They are either *germinal or acquired;* that is, they were either inherited from a preceding generation or were acquired *independent of heritage.* It is often extremely difficult to determine under which of these heads a character should be classed. For example, a family of white people accustomed to a temperate climate has moved to a tropical environment. The parents and children will very likely become tanned as a result of the new conditions. *Subsequent children will also exhibit the same skin color.* Is this due to the *transmission of an acquired character,* or is it due to the fact that these children, too, are ***subjected to the same environment*** as their parents, brothers, and sisters? Many casual thinkers would be quick in attributing this change to the inheritance of acquired characters, while, in all probability, the germ plasm has not been altered. Too often is it the case that a sharp line cannot be drawn between germinal characters and characters which are acquired independently of heritage. Many acquired characters pass for germinal characters when such should not be the case. In general, germinal characters are definite traits which are repre-

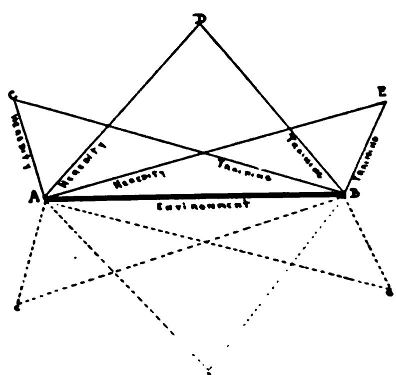

FIG. 127. The Triangle of Life—The Old Idea. According to this idea, *environment* is the determining factor in our lives.

sented by factors in the reproductive cells and which normally pass on to the next generation; acquired characters are those which come thru somatic modifications which are in no way connected with the germ cell mechanism, and their possession is wholly a matter of chance or circumstance.

The Triangle of Life.—Since the whole problem of acquired characteristics needs very careful scrutiny, it seems wise to review briefly a few of the most fundamental principles before considering the subject in detail. This is especially necessary since much of the matter presented in the preceding chapters is essential to an understanding of the problem in hand.

The development of the characteristics of the individual depends wholly upon three factors: *heritage, environment,* and *training.* The relative importance of these factors has been a subject of debate for many decades. The earlier workers laid little stress upon heritage, but claimed that the environment was the dominant factor in the life of every individual. According to this idea, the base of life's triangle was environment, and heritage was a subordinate consideration along with training. Around this substantial base (Fig. 127) would swing the other two factors. Upon the old conception

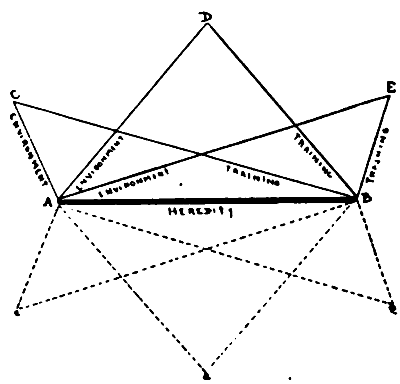

Fig. 128. The Triangle of Life—The New Idea. According to this conception, what we are (heritage) is far more important than what we do (training) or what we have (environment).

were founded many of the codes of reform which are the working basis for our social institutions of to-day. Many reformists will still contend that a child will act in response to his environment no matter how low his heritage may be.

Recent investigations have revealed the fact that the old notion of the triangle of life is not the correct one. The dominant factor in the life of the individual as well as of the race is *heritage* (Fig. 128) rather than either environment or training. Heritage expresses the inborn nature of the individual. Instinctive tendencies, for instance, are part of the *inborn* equipment with which each and every individual is endowed, and which are due to heritage. Environment and training, although subsidiary, are by no means inconsiderable. It is a truism of our every-day life that the environment renders a marked effect upon the individual. Compare the bleached skin of the bank clerk with the brown and leathery face of the farmer. As boys, they may have been almost identical. Obviously, the sun's rays and the wind affect the color and composition of the skin. Who would dispute that the environment in the form of use has caused the blacksmith to develop a strong, muscular arm? Whether or not these environmental changes will be inherited by the next generation is a question of fundamental importance in the evolution of the race.

Biologists maintain that what a man *is* has a greater significance than what he *has* or *does*. Training and environment may better the present generation but a *good heritage* is the *only salvation* of the generations unborn. No amount of education can extinguish the outcroppings of an undesirable heritage. *Heredity is branded in the germ plasm and cannot be eradicated by any force of nature. Proper environment and training may serve as a check on hereditary tendencies in the individual but to remove them from the germ cells and prevent their transmission is an impossibility.* To trace the stream of heredity that has been flowing onward in the past bearing us upon its bosom, to chart its shoals and reefs, to divine its future course, and to direct its flow into new and better channels so that it may go on unobstructed to its final goal, is the all-absorbing problem that confronts the modern geneticist.

Pangenesis, Continuity of the Germ, and Modified Pangenesis.—All forms of life existing upon the earth at the present time have arisen from previous and simpler forms. This, in substance, is Darwin's theory of descent. According to this theory, all animal life has sprung from a few primitive types. This theory of evolution, then, amounts to the practical assertion that all animal life is more or less related. From one or more unicellular forms have arisen the great number of multicellular forms that now exist—man included. In the popular mind, Darwin's theory of descent is supposed to be that man sprang from the apes. Strictly speaking, this is a misconception of the grossest sort. Darwin's theory does not put forth the idea that man sprang from any particular species of apes, but rather that man and the apes have *both* come from a *common stock*. (See Chapter IV.) It is equally true, according to the same theory, that man and many other of the lower animals have a common origin in the remote past. Essentially, then, this theory is not a theory of the descent of man from any particular species but a theory of the relationship of all animals thru their common ancestry.

By what process has this development taken place? How has it been possible for the simple to develop into the more complex and thus form a more or less connected chain from "amœba to man"? Was Lamarck correct when he stated the fundamental principle of the philosophy of evolution as follows: "All that has been acquired, begun, or changed in the structure of individuals in their life time, is preserved in reproduction and transmitted to the new individuals which spring from those which have inherited the change" (Lamarck's *Zoölogical Philosophy*)? Erasmus Darwin, the grandfather of Charles Darwin, was a strong supporter of this view that evolutionary development was simply an accumulation of the reflected daily experiences of the individual which were handed on to the next generation. Even Charles Darwin and Herbert Spencer accepted this theory as one of the main factors in the development of the race.

Darwin put forth the theory that all parts of the body were constantly sending contributions to the germ cells in the form of "gemmules." These hypothetical units then reconstructed the whole individual, including his modifications in the germ cells. This theory readily allows for the transmission of acquirements. There is, as a matter of fact, no tangible basis upon which to rest this hypothesis. This theory of Darwin, the theory of *pangenesis*, is in direct contradiction to the theory of the continuity of the germ plasm which is the present-day accepted view. Pangenesis, essentially, holds that the soma gives rise to the germ and that the germ, in turn, gives rise to the soma of the next generation. According to this erroneous conception, the hen produces the egg and the egg, in turn, produces the hen. This process of interchanging from germ to soma and from soma to germ is repeated in each succeeding generation. Figure 129 will help to visualize this process. It is almost a self-evident fact that this theory of pangenesis cannot be a true one. Under it, the transmission of parental modifications should reach a plane of almost infallibility—a condition which very evidently does not exist.

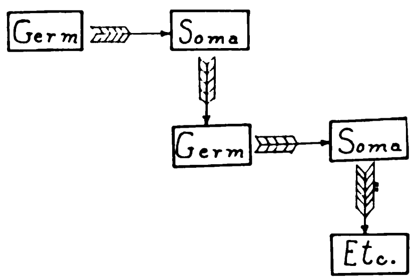

FIG. 129. The Theory of Pangenesis. The earlier biologists held the erroneous conception that the hen produced the egg and the egg in turn produced the chick.

Weismann was the first to deny flatly all transmissions of acquired modifications. Since it was impossible for him to conceive of any mechanism whereby any particular acquired character could be handed down to the next generation, he began to cast about for a more plausible explanation. Although Weismann was quite destructive in his claims, his logical constructive arguments gained popularity at once. He attempted the substitution of a plausible theory for the one which had no established foundation. His principal arguments were intended to destroy the theory of Darwin. In opposition to Darwin's views, Weismann objected that no known mechanism existed for the transfer of characters from the soma to the germ. In his own words, his claims are that: "No such modifications of the soma (effected by environment or use and disuse) can be transmitted to the germ cells from which the next generation springs. They are, therefore, of no account in the transformation of species. Characters can only be inherited in so far as their rudiments are already given in the germ plasm. Modifications which are wrought upon the formed body in consequence of external influences must remain limited to the organism in which they arose."

It is obvious from Weismann's own statement that he considered the germ cells absolutely distinct from the somatic cells of the body. According to this conception, it would be impossible for the long neck of the giraffe (Fig. 95) to have been caused from stretching in order to reach the foliage on the trees. According to Lamarck's view of this case, each succeeding generation of giraffes inherited the stretched neck of the previous generation until the race acquired its present neck length. When we remember that the determiner for neck length is tucked away not only in the germ cell but in a definite chromosome, it is difficult, indeed, to conceive a possible way for it to be influenced by somatic changes. How absurd it is to even suspect that the stretching of the neck could "stretch" this tiny determiner which is so small that it cannot be observed even by the aid of the most powerful microscope. If the soma affects the germ cells, as Darwin considered, why are not such effects more commonly seen? We can excuse the earlier workers for their erroneous theories, because in their day scientific knowledge had not advanced sufficiently for the truth to become evident. Mendelism, and the chromosome theory, at that time yet remained to be formulated. The old hypotheses, however, have not been without value, for they have served as a stimulus to investigations into the facts.

The theory that Weismann advanced in opposition to pangenesis is known as the theory of the *continuity of the germ plasm.* According to this theory, the germ plasm flows onward from generation to generation in one continuous stream (Fig. 130). The somatoplasm is in no wise the originator of the germ; but, rather, is itself derived from the germ plasm. This plausible theory holds that the egg not only produces the hen but also the germ cells, and thus the future eggs of that hen. This conception, which claims that the egg produces the individual but that the individual does not produce the egg, holds true with all the higher animal forms. This theory does not allow for the modification of the germinal characters thru acquired somatic characters. The fact that very early in the development of the individual definite cells are set aside to

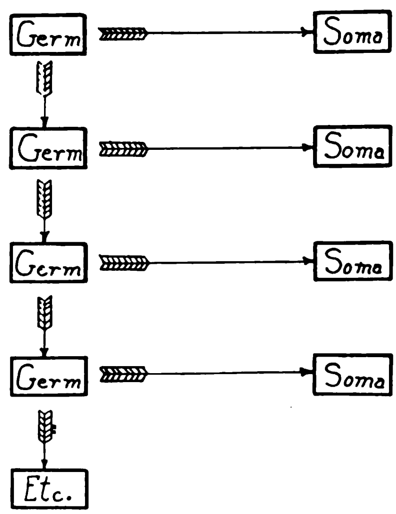

Fig. 130. Continuity of the Germ-plasm. According to Weismann's views the egg produces both the hen and the egg of the next generation.

become the future functioning reproductive cells of that individual would lend support to Weismann's views.

Another interesting theory has been advanced in which both the pangenetic theory and the theory of the continuity of the germ plasm are combined into one. In this theory it is supposed that the germ plasm is continuous from generation to generation in the same way as Weismann thought, but that somatic modifications would occasionally become fixed in the germ and be heritable (Fig. 130). This theory, which is known as the theory of *modified pangenesis*, would seem, at first glance, to be a very plausible one; in fact, there is some experimental evidence which seems to support it. According to Kamnnerer, certain artificially striped salamanders, whose stripes were obtained by keeping the animal (when young) on a yellow background, produced striped offspring. The experimenter then crossed spotted salamanders with natural striped ones and obtained spotted offspring, showing that "spot" is dominant over "natural striped." However, upón crossing spot with artificial stripe he was surprised to find offspring with broken stripes or, rather, spots in rows—another clear-cut case of the acquired character's affecting the germinal constitution of the individual. With these facts established, ovaries of one type were transplanted into the body of another, somewhat as Castle (Fig. 131) did with the black and white guinea-pigs. Ovaries from a naturally striped individual were grafted into the body wall of a spotted female and a cross between this individual and a natural striped male gave all striped offspring. Similar results were obtained when ovaries from an artificially striped female were used. Similarly a natural striped female containing "spotted" ovaries crossed with either a spotted or natural striped male produced spotted offspring. This would be expected, since "spot" is dominant.

However, most unusual results were obtained when *artificially striped* females whose ovaries had been supplanted by those from a spotted individual were crossed with either of the three types of males. When such a female was crossed with a spotted male one would expect all offspring to be spotted, since this is equivalent to mating two spotted individuals. However, only 19 out of 79 offspring conformed with expectations, as the remaining 60 had spots in rows. When the *artificially* striped female containing "spotted" ovaries was crossed with a natural striped male, all offspring should have been spotted if the somatic cells had no influence over the germ. This, however, was far from the case. In like manner the somatic cells seemed to have had inductive effect upon the "spotted" ovaries when the above considered type of female was crossed with an artificially striped male, as the 209 off-spring from four different females were all striped instead of having spots in rows as in the case of the preliminary crosses.

If it is true that the implanted ovaries were changed by the body cells of the females in which they were implanted; if "hereditary induction" did take place so accurately that the spots of the parents were reflected, so to speak, through the specific "spot" determiner on the body of the baby salamander, if all this is actually true, as the results seem to indicate, why then did not the same thing happen when the corresponding crosses were made with females with natural stripes? How is it possible for such precise induction to take place in an artificially striped female when nothing of the kind occurs in those bearing natural stripes? Were it not for such unanswered questions, Kamnnerer's experiments would lend very strong support to the theory of inheritance of acquired characteristics. It should be said, in general, that of the many experiments designed to establish this theory as a fact, certain fallacies are, in each case, quite obvious.

Use and Disuse.—It is believed by those who hold the affirmative of the question of the transmissibility of acquirements, that the long hind legs of the jumping animals (such as rabbits and kangaroos) and the long front legs of the climbing animals (such as monkeys) were acquired thru constant use.

The fundamental questions to be asked in this connection are: Do the rabbits and the kangaroos have well developed hind legs because they have used them, or do they use them because they have them? Do the monkeys have long forelegs because they have used them, or do they use them because they have them?

Similar questions may be framed for all cases in which there seem to have been inheritances of parental modifications. In the light of our present knowledge, we are justified in concluding in all such cases that the second proposition—the one opposed to the inheritance of acquired characteristics—is the accepted one. What, then, have been the agents by which evolutionary progress has been fostered? This question can be answered thru a reference to the causes which have already been considered more or less in the preceding chapters. These were *environment, adaptation, natural selection, variation, prodigality of nature, mutation, amphimixis, and hybridization.*

Environment, Adaptation, and Natural Selection.—In order to survive, all living things must be adapted or be capable of adapting themselves to their surroundings. In a stable environment, animals and plants become so well adjusted that they remain unchanged or they undergo comparatively little modification. Evolution is most rapid where the environment is unstable.

For an illustration of environmental change, consider the time when all animal life was aquatic, when the water of the sea was comparatively fresh. Thru a process of inorganic evolution, the present continents appeared above the water. This new condition caused the water of the seas to gain greatly in its percentage of mineral matter in solution—particularly calcium and sodium salts. This was probably brought about largely by the work of the rivers in bringing down the minerals which had been dissolved thru a process of erosion. The animal life met a new situation since their physiological make-up was not in harmony with their environment. A readjustment had to be made. Any one of three possible courses was open to them. They must either adapt themselves to the new environment, modify their systems to throw off the excessive mineral matter, or leave the water entirely. Not all met the situation by any one of these means. Some did adapt themselves by undergoing physiological changes, others modified themselves and became the ancestors of such forms as the modern corals and shell-bearing fishes. Others were unable either to adapt or modify themselves but were forced to migrate to the land. Of the vast number of individuals that attempted to meet the situation in this manner, perhaps *only a very few* were able to meet the rigid requirements of their new environment. This select number of individuals laid the foundation for all animal life upon the land. Granted the fact that the above situation was true, how was it possible for the adaptations and modifications to take place? Was it thru the inheritance of gradual parental modifications in the desired direction, or by natural selection acting upon those which had a variation or a degree of adaptability of a favorable nature?

It is almost a tradition with the populace that the cave fishes are blind because they are in the dark caves and have no use for eyes. This answer is especially satisfactory since, in most cases, the blind species are plainly derived from the fishes of the surrounding regions which have normal, well developed eyes. In response to the question as to the origin of the blind fishes, the author generally asks his students this question: *Are blind fishes blind because they are in the cave, or are they in the cave because they are blind?* This suggests the probability of their being blind before they entered the cave.

What *proof* have we that the fish's eyes disappeared because "it lived in a dark cave and had no use for them"? How many years does it take for a family of fishes with normal eyes to undergo such a physiological change as to be left without eyes, save small rudimentary and functionless ones? How many generations? (Payne reared flies in the dark for 58 generations without appreciable effect.) We have repeatedly referred to the fact that the determiners for heritable characters are located in the chromosomes in the nucleus of the germ cell. This holds true in the case of the fishes as well as in other forms. Here, then, we have an interesting situation. The *absence* of light sets up a nervous stimulus which passes to the brain, thence into the abdominal cavity to the gonads (sex cells), and by some mysterious process removes from the chromosomes the determiner which stands for normal eyes. In other words, a nothing removes a something.

Let us go back in our assumption to the early history of the cave. At one time, the cave lake was in most cases continuous with the water on the outside—making it possible for the fish to play in and out the mouth of the cave. Suppose a fish should have been born without eyes; that is to say, a *mutant*. Since it had no eyes with which to see the approaching enemy, its struggle for existence was greatly intensified. If, perchance, it should have found its way into the cave, its pursuers would have been very much inconvenienced because their normal eyes would have been useless in the dark. The blind fish would have the advantage because of its other senses being especially well developed, since it depended upon them and not upon sight. Under these conditions, the normal fish may have become the prey of the blind ones. The latter, finding the dark environment favorable for a quiet and undisturbed existence, adopted the cave waters as its home. After the outside waters were disconnected, these fish were cut off and remained blind cave dwellers. Thus, it appears that the blind fish "*are in the cave because they are blind.*"

Many investigators have commented upon the fact that immigrants very often change in such a way that they seem to acquire the racial characteristics of the people among whom they have settled. Commenting upon this point, Popenoe and Johnson have said: "The many instances quoted by historians, where races have changed after immigration, are to be explained in most cases by natural selection under new conditions, or by interbreeding with the natives, and not as the direct result of climate. Ellsworth Huntington, the most recent and careful student of the effect of climate on man, finds that climate has a great deal of influence on man's energy, but as far as inherited traits in general are concerned, he is constantly led to remark how little heredity is capable of being changed." Furthermore, Jordan and Kellogg say: "Influences of climate, of heat, and of cold are not inherited so far as experiments show, nor has it been made clear that extrinsic influence exerted on the individual really modifies the forces of heredity."

Environment, adaptation, and natural selection are three of the most important factors in the evolutionary process. Survival is a matter of adaptation to environment. Natural selection eliminates the unfit. In the examples cited above, these three factors play an important rôle in the perpetuation of the race fitted to live in its own particular environment. It now becomes necessary to review briefly the means that nature has devised in order to furnish material for these three factors to work upon.

Variation, Prodigality of Nature, Mutation, Amphimixis, and Hybridization.—It will be unnecessary to give more than passing notice to these factors since all have received more or less attention in previous chapters. Variation is a universal law of nature. The members of a species are not all exactly alike. Natural selection is given an opportunity to act upon the variants in order to weed out those which do not harmonize with their environment. The prodigality with which Nature reproduces a species affords ample latitude in this process of the elimination of the unfit and the preservation of the fit. Nature is very prodigal. She does not limit the number of individuals in any species. Their propagation is determined by the factors of environment, adaptation, and natural selection. It is the factor of variation that forms one of the most fundamental principles upon which evolution finds a foundation. The prodigality of nature affords an excellent chance for the occurrence of wide variation, mutations, and the intermixing of species. Amphimixis and hybridization are phenomena of the intermixing of two distinct lines of germ plasms. It is evident that under such conditions a new hybrid type would be produced. Again, natural selection would come into play in the elimination of the unfit and the perpetuation of the fit.

Induction.—Experimental evidence shows that the germ cells of the individual may be affected inductively, and, thus, individual conduct may in a measure have a direct influence—although not truly hereditary—upon the offspring. *The phenomenon of induction may be defined as a temporary derangement of the germ cell mechanism* which is brought about thru improper nutrition or "poisoning."

The germinal constitution of the guinea-pigs which Stockard exposed to air saturated with alcohol seemed to have been affected inductively. Many of the young died or were born dead, others were deformed and epileptic. Even the third generation was affected by the action of the drug upon the germ cells of their grandparents. However, this effect is transitory—it gradually disappears under normal conditions. Similarly, Sumner found that tail length in mice was affected by temperature and that the modification was passed to the next generation. While considering such cases as those just cited, Conklin concluded: "Probably environmental stimuli acting upon germ cells at an early stage in their development may rarely cause changes in their hereditary constitution; but changes produced in somatic cells do not cause corresponding changes in the hereditary constitution of the germ cells. Germ cells like somatic cells may undergo modifications which are not hereditary; they may be stained with fat stains and the generation to which they give rise be similarly stained; they may be poisoned with alcohol or modified by temperature and such influences be carried over to the next generation without becoming hereditary. All such cases are known as *induction* and many instances of the supposed inheritance of acquired characters come under this category."

We cannot conclude that induction is universal and infallible in all cases where the germ cells are laid liable to certain effects. These cells are so carefully guarded that it is nearly impossible to reach them to do them harm; nevertheless, such does seem to occasionally happen. However, many experiments have been performed that have given results which seem to contradict those of Stockard and Sumner. Among these may be mentioned the experiments of Pearl, who treated 19 fowls with alcohol with but slight effect upon general health and none upon egg production. Commenting upon the work of Pearl, Popenoe and Johnson say: "From their eggs 234 chicks were produced; the average percentage of fertility of the eggs was diminished but the average percentage of hatchability of fertile eggs was increased. The infant mortality of these chicks was smaller than normal, the chicks were heavier when hatched and grew more rapidly than normal afterwards. No deformities were found. 'Out of 12 different characters for which we have exact quantitative data, the offspring of treated parents taken as a group are superior to the offspring of untreated parents in 8 characters,' in two characters they are inferior and in the remaining two there is no discernible difference. As far as reported, it shows that what is true for guinea-pigs may not be true for other animals, and that the amount of dosage probably also makes a difference. Dr. Pearl explains his result by the hypothesis that the alcohol eliminated the weaker germs in the parents, and allowed only the stronger germs to be used for reproduction."

In the case of man, it is very likely that the body can absorb a certain amount of such poisons as alcohol without any perceptible effect upon the germ cells. When the limit is passed, those cells which are weaker than the others will be the first to suffer. When a point of saturation is reached, the stronger cells may be affected inductively. If we are to judge from the results of Stockard's experiments, the children thus affected are likely to be defective in various ways—low vitality, degenerate, paralytic, deformed, and otherwise defective, while Pearl's results seem to suggest a kind of elimination of the "Unfit" germ cells. In all cases the preponderance of evidence is against the use of any such poisonous substance as alcohol, tobacco and opiates.

Mutilations.—Many attempts have been made to prove to the biologists and to the public in general that acquired characters such as mutilations are handed down to later generations. The most notable of the experiments along this line were those of Brown-Sequard on guinea-pigs. The sciatic nerve was cut or certain other injuries were made to the spinal nerve which caused pronounced epilepsy. This experiment was tried upon thousands of guinea-pigs and in a *few* cases the offspring from these mutilated parents were epileptic and showed morbid conditions of the nerves the same as did their parents. Altho the experiments of Brown-Sequard are somewhat convincing, they are not confirmed by those of later workers. Thompson suggests that "the probable interpretation is that the artificially induced epilepsy liberated a toxin which affected the germ-cells in some cases, the germ-cells and fœtus in other cases."

Many examples may be cited which directly prove that mutilations are not handed down in the slightest degree. It is the custom in many localities to cut off the tails of the pigs when they are very small, but still tailless pigs are not born into these families of animals. In like manner, hornless cattle are not born because of the custom of "dehorning" the parents. The "Flathead" Indians admire a head which slopes from the tip of the nose to the crown. In order to bring this about, a board is fastened to the forehead of the baby while the skull is yet plastic. Although heads have been flattened for unknown generations, no children have been born into this tribe with natural flat heads. Neither is there recorded an instance of a Chinese girl (Fig. 96) being born with abnormally small and deformed feet (other than club feet, which deformity is quite common among all races), even tho the binding of the feet of women has been practiced in China for unknown ages—at least 6,000 years. It has been said that the reason that modern man has a degenerate little toe is because he has acquired that character thru the modifications of many generations of shoe wearers. The mummies of the ancient Egyptians show the same characteristic with regard to the little toe. Certainly, they cannot be accused of wearing tight shoes!

"Mutilations of any sort are not inherited. The tails of sheep have been cut off for countless generations. Yet each lamb is born with a tail. This law holds good for docked tails, docked ears, pierced ears, and the many mutilations to which domestic animals and men have been subject since the beginning of civilization" (Jordan and Kellogg). A lady of no mean distinction, who was a graduate of a leading university, assured the author that her son had caused the production of a race of tailless dogs by amputating the tails of the parents for several generations. The story within itself is absurd enough, but the very height of absurdity was reached when it was claimed that the producer of such animals was a mere high school boy. Thousands of generations of de-tailed dogs would not give rise to a race of tailless ones. If we could alter nature by such a rapid process, all living things would soon conform to man's ideals! Humphrey very aptly said: "If we make a jack-o'-lantern out of a pumpkin, and afterward plant the seeds, we do not expect a crop of jack-o'-lanterns. Repeat the cutting and plant the seeds thru fifty generations of pumpkins; not a jack-o'-lantern will be grown. The inheritance is from the seed, not from the pumpkin."

Supposed Inheritance of Acquired Characters.—Any number of examples might be cited in which the environment together with use and disuse seem to have rendered direct effect upon the race. In certain parts of the Alps, families have been guides for tourists for many generations. It is needless to say that the mountaineers are a large and sturdy race of people. Is this due to the fact that the children have inherited the sturdiness acquired by their parents, or is it due to the direct effect of the healthful climate and the outdoor life? In other words, would not the son of a decrepit shoemaker be equally as sturdy were he adopted by the Alpine parents when a babe and reared under that environment? On the other hand, would not the Alpine child develop into a scrawny weakling were he to live the life of such a shoemaker?

When certain lowland plants are reared at high altitudes, they become dwarfed and sometimes covered with hairs. The flowers of such plants are also much more brilliant under the new conditions. The "scrub oak" which is so common in the Rockies is thought to be derived directly from the giant oaks of lower altitudes, the difference being due to the inheritance of acquired characters produced by adaptation. It is a well known fact that the northern varieties of corn (notably the Peep o' Day) mature in a much shorter time than do the varieties grown in the southern states. Since all forms of corn were supposed to have originated from a tropical plant, and, further, since the northern varieties *continue to mature*

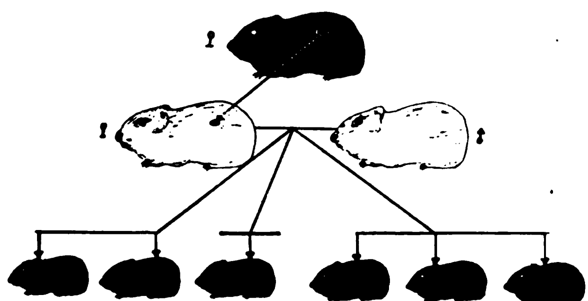

FIG. 131. Heredity overrules environment. A diagrammatic representation of the transplantation experiment performed by Castle and Phillips. As the illustration shows, the ovaries of a white guinea-pig were removed and those of a black individual grafted in their place. The white female upon being mated to a normal white male, produced three litters of black pigs. This clearly shows that the somatic cells of the white female, which possessed "black" ovaries, had no influence upon the germ cells.

quickly if planted in the south, it is claimed by many that the characters acquired thru adaptation to the environment have been inherited. The above cases are fair samples of a whole class which appear—if not carefully scrutinized—to be substantial and convincing proofs that acquired characters are inherited. To this list might be added many others. The explanation for such cases as the scrub oak and the corn is that natural selection has been acting upon mutants, variations, or the products of amphimixis or hybridization. Natural selection eliminated the unfit and perpetuated the fit.

Germ Distinct from Soma.—Experiments show that the somatic or body cells render little, if any, influence upon the hereditary potentialities of the offspring. One of the most conclusive of these experiments was that of Castle and Phillips. The guinea-pigs pictured in Figure 131 show the results of one of their most successful investigations. The ovaries were removed from the black female and grafted into the body of the white female guinea-pig in place of her own ovaries, which had been removed. Thus, the animal is white but possesses the ovaries of a black guinea-pig. Three times she was successfully bred to a white male. The three litters are illustrated. All were *black.* The first litter was composed of two black pigs (A and B), the second of one (C), and the third of three (D, E, and F). The fact that the mother died before the last three were born and that they were removed by operation does not detract from the results. It is noted that the results were exactly the same as if the black female had produced the litters rather than the white female. In fact, the black female was the true mother as her germ cells produced the young, while the white female served only as an incubator. Since black is dominant over white, all the progeny should have been and were black. The fact that the somatic cells of the white guinea-pig did not change the hereditary constitution of the "black" germ cells —tho in the body of and nourished by the white animal—shows that the normal hereditary tendencies persist regardless of environmental changes.

Conclusion.—Throughout the above consideration, the original view of Weismann that the germ plasm is distinctly independent of the body cells has been the basic principle. It must be conceded that Weismannism has undergone certain modifications and that the germ cells may be altered. However, this concession does not weaken the arguments against the inheritance of acquired characters. In cases where germinal modifications have been known to take place, the germ cells have been changed *directly* rather than thru the soma. The pangenetic theory has become obsolete for all time. Will the son be a drunkard because the father was? If the pangenetic theory of acquirements held true, we should become a race of "beer kegs" before many generations. A man acquires the taste for strong drink; he does not inherit it. The son of a drunkard may inherit the physical and mental debility of his father and thus be more susceptible to temptation and the acquirement of an appetite for strong drink. However, we cannot be assured that alcohol does not have an *inductive* effect upon the children even to the "third and fourth generation." After reviewing the situation as presented in this chapter, we are forced to admit that the inheritance of parental modifications does not play any part in the progress of the race. That "*wooden heads are inherited and wooden legs are not*" is a truism.

Nature is very wise. She has ordained that there shall be no promiscuous handing down from generation to generation of the various parental modifications or acquirements. By this all-seeing measure, she has prevented a hopeless struggle for survival between the good and the bad qualities of our race. Rather, the energies of existence are bent toward a more perfect adaptation in order that the race may be lifted to a still higher plane and be perpetuated to the utmost limits before it shall have completed its life cycle. Progress is effected by the various creative factors of evolution such as variation, mutation, etc. The formative factors acting upon these are the instruments of determining which characters shall be perpetuated. The accomplishment of the aims is found in the inviolable continuity of the germ plasm which renders a worthy character permanent rather than temporary.

CHAPTER XXX

MOULDING THE SUPER-MAN

Final "Evolution of Man"—A Broader View Necessary—Our Attitude—The Unfit Work an Injustice upon Society—Eugenic Responsibility—Human Inheritance—The Jukes—The Edwards—The Kallikaks—Relation of Degeneracy to the Community—Inequality of Men—Overproduction of Inferior—Limiting the Unfit—Sterilization—Informing the Public—Public Opinion—Biologic Enlightenment—Human Responsibilities—Selection of Mates—Status of Marriage Relation—Production of Children—Quality vs. Quantity—Eugenics and Religion—Marriage, Birth, and Religion—Responsibility of Marriage—Religion Must Embrace Eugenics—Relation of Science and Religion—Supreme Ruler of the Universe—Conclusion.

"Virtue does not come in life until reason is developed.

We have long since emerged from the heroic childhood of our race, when good and evil could be met with the same frolic welcome. . . . It remains for us to throw aside the youthful over-confidence. . . . We are grown men and must play the man."

—Huxley.

A study of the various inhabitants of this earth prior to the advent of man (See "Cycle of Life," Chapter VI) suggests the possibility of the appearance in the future of some type of being which will be much superior to the present all-dominating master—*man*. It was suggested that this superior being may appear as an entirely new type of life or as a new race possessing the physical make-up of man as he is known to-day but with a superior intellect. The "Cycle of Life" indicated further that some five million years has been the average time for any one species to dominate the earth. Supposing that man, as such, has been in existence the maximum length of time assigned to him by the most conservative calculator—namely, less than a million years—indications are that over four million years remain for him to dominate the earth. If intellectuality be considered, his time might be extended indefinitely; it may be extended to the time when the changing of the earth's condition will make it impossible for him to live.

Even tho the geologic succession of ages has been dominated by first one species and then another in a cycle of supremacy, man has reached a plane from which he will probably not descend. The brutes which have held sway in the past gained their ascendancy either thru physical powers or thru changed environmental conditions. They were creatures of circumstance; they held the supremacy, for the time being, because their environment was such that their own peculiar natures fitted them for their positions of power. They were powerless to act against circumstance. When the environment changed, presenting new problems of existence, these creatures were unable to meet the vicissitudes of life and gave way to others that before may have been oppressed and barely able to keep up in the struggle for existence but which were then able to assume the mastery. Not so with man. He has reached his place in the world thru the exercise of intelligence—a factor which he holds in common with a majority of his fellow-beings, but to a far greater degree. *Environment has no terrors for man; he moulds it to suit his ends.* It has been truly said that man carries his environment with him. The question, then, is not what species shall succeed man but to what plane shall man, thru his endowment of intellect, rise in the years of the distant future.

Since it is an indisputable fact that man is playing a great part in the moulding of plant and animal life, it should be logical to conclude that he is a co-worker with nature in the moulding of the so-called super-man. If each generation should coöperate with the natural forces in the ushering in of the generation unborn, man might be developed to such an extent that he would indeed be only "a little lower than the angels" and "crowned with glory and honor." Man is but a savage with a coat of veneer. Even the most polished of us are savages at the core. Much of the evolutionary lumber which was at one time a useful part of our existence is still carried on as a part of human nature. Human nature has evolved out of the jungle into the open, but a great deal of the past still clings to it.

In fact the cause of feeble-mindedness and various other defects might be explained in terms of evolution. Davenport so says: "If hereditary feeble-mindedness depends upon the defects in the chromosomes, such defects may well have persisted in the germ plasm for many generations. Although we must concede the probability that mutations are commonly occurring in the nervous mechanism as they do in other bodily organs, still it is probable that many existing cases of mental defect can be traced back to the remote past. In the most extensive pedigrees of the feeble-minded that have been made in this country, like that of the Jukes and of the Kallikak family, the mental defect has been traced for nine or more generations. If it can thus be traced back 200 years, there is little doubt that in some cases it might be traced, where there are sufficient records, thru 2,000 years or even more. There is good reason for believing that the normal man of the old Stone Age in Europe would be considered to-day a moron, if not an imbecile of a high grade. To-day there exist in Australia remnants of a native race, the normal individuals of which are characterized by distinctly lower capacity of mental development than the normal European. In this race therefore, practically 100 per cent are morons to-day. It is probable that in out-of-the-way places in Europe there persist groups of individuals who inherit the mental insufficiency of the old Stone Age. Representatives of such groups have come to America. They have been segregated thru the pressure of social environment; they have married each other and their descendants persist among us to this time. *It is not* *improbable, accordingly, that certain of our feeble-minded families have not become such through a secondary loss of the capacity for full mental development but are the survivors among us of a low state of mental development such as characterized the ancestors of all of us."*

In order to bring about a marked evolution of man; in order to change him from a brutal twentieth-century warrior into a perfect being moulded "in His own image," it will be

Fig. 132. Kansas State Training School (for Feeble-minded). Approximate investment of three-quarters of a million dollars. Expenditures for 1921 were $157,028. During the year the amount for each defective was $201.68. One feeble-minded woman has been in this institution for forty years. At this rate, this woman has been quite a burden to the wheat growers. In 1919 this institution had 644 inmates; in 1920, 667; in 1921, 729. The Eugenicists feel that it is time to think of the unborn.

necessary to broaden our vision from a narrow view of the present generation to that of the unborn. Walter was correct when he said, "The lives of the unborn do not force themselves upon the average man or woman with the same insistency as the lives already begun." After all, it is the unborn that give us the key to the future—the living are beyond eugenic reach.

Regardless of the fact that we are still more or less circumscribed in our racial conceptions, marked transformations may be observed. It may be noted, for example, that the doctor's sole business not so very many years ago was to administer treatment to the sick; now the medical world is concerned more with disease prevention than disease cure. In like manner, the policeman's duty has changed from that of crushing the skull of the "drunken brute" to the sacred duty of crime prevention. Out of the latter has grown the science of criminology which has as its true function the recognition of criminal types and their treatment in such a way as to *prevent* the logical outcome. Far behind these two great systems of human improvement, we find the social reformers with their delicately woven nets of orphanages, insane asylums, homes for the feeble-minded (Figs. 132-133), reform schools, poor farms, and various local charitable institutions to care for the social outcasts of the present generation. Few plans are provided for the *unborn* save possible drives for increased endowments in order that the reformers may be in a position to care for the almost unrestricted increase. It is this unrestricted increase which presents the most serious problem which the modern eugenicist who has hopes for the future of the race has to face.

If seriously considered, it seems quite an injustice for the average citizen to be burdened by taxation or by subscriptions in order to maintain a modern "poor house" in which are to be housed many of the country's lowest human trash who never before had so much as seen inside of a respectable home. "Some achieve greatness" but these most certainly have "greatness thrust upon them." The writer does not advocate the elimination of the charitable institutions but he does contend that the progressive citizens of every community should be made to feel their *eugenic* responsibility. One writer has very aptly said, "The greatest foe of eugenics, next to indifference, is ignorance. Science is just beginning to feel its way in the field while the people have yet to unlearn many prejudices." It is a truism that but few of the races of mankind are progressive. And, further, it is true that only a few individuals of these so-called enlightened races are progressive.

Fig. 133. These typical Mongolian dwarfs (ages, left to right, 34, 27 and 38) shown in comparison with the average sized man. (The man in straight jacket is a monomaniac for tearing his clothes.) The lower figures show the usual facial expression of the Mongolian imbeciles when they are not molested. Herrman (17), after a thorough study, concluded that Mongolian imbecility is a recessive Mendelian trait, the parent usually showing a decided neurotic condition.

Man, in general, is subject to inertia. He clings to the habits and thought of the past. Ideas and prejudices which were formed in days gone by, still persist. The mass of us must cast these old views aside and face the facts in their true aspects, even tho the facts might seem discouraging. The unfortunate aspects of human society can be discussed without the least amount of pessimism. Henry Fairfield Osborn says that "a pessimist is one who will *not* face the facts" while "an optimist is one who faces the facts but is never discouraged by them. The optimist in science is the one who delves afresh into nature to restore disordered and shattered society . . . To know the worst as well as the best in heredity; to preserve and select the best—these are the most essential forces in the future evolution of human society" (*Science*—Oct. 7, 1921). The value of knowing the worst as well as the best will be understood only thru proper eugenic education.

Fundamental to an eugenic education is a realization that the principles of heredity are applicable to the human race as well as to plants and animals. Man is as truly an animal as an oak is a plant. Man, from the standpoint of both physical and psychic existence, has come to be what he is thru evolution, and, evolution has its basis in heredity. In substantiation of the various contentions that have already been made to the effect that heredity applies to man, it should be noted that in the case of the well-known Jukes family the children, grandchildren, and great-grandchildren of *Belle* were predominantly sexually immoral; those of *Ada* were criminals; those of the third sister, *Effie,* were largely paupers. It might be said, in general, that when the details of almost any family history are known, it immediately becomes obvious that individual physical, mental, and moral traits appear in accordance with established laws. This fact alone shifts the final solution of social problems to the unborn.

That superior and inferior family traits are inherited is convincingly shown by contrasting such families as the Edwards and the Jukes. It is not at all probable that environmental differences would account for the divergencies shown in the following chart.

Jukes	*Edwards*
Original stock: "Max Jukes," intemperate, shiftless, and illiterate.	Original stock: Jonathan Edwards, eminent divine.
2094 persons traced.	1394 persons traced.
Not one had a common school education.	295 college graduates; 13 presidents of colleges; 60 physicians; 100 clergymen and missionaries; 60 prominent authors and writers; 100 lawyers; 30 judges; 1 Vice-President of the United States; 3 United States Senators; several governors; framers of state constitutions; mayors of cities; ministers to foreign courts; 1 president of the Pacific Mail Steamship Company. 15 railroads, large industrial enterprises, banks and insurance companies have been benefited by their management.
140 convicted criminals. 7 murderers.	Not one ever convicted of a crime.
300 immoral women.	Every woman above reproach.
310 paupers.	Every individual progressive and thrifty.
600 feeble-minded or epileptic.	All normal or above.
Only 20 learned a trade, 10 of these in prison.	Family permeated with successful professional men and tradesmen.
Not a soldier of high rank among them.	75 officers in army and navy.
Family cost society $2,500,000.	"Almost if not every department of social progress and of public weal has felt the Impulse of this healthy long-lived family." —Winship.

A still more convincing case showing the effect of good or bad blood on the children may be found in the progeny of Martin Kallikak. While "sowing his wild oats," Martin took advantage of a feeble-minded girl, and, as a result of this illegitimate mating, a child was born whose descendants were more or less comparable to those of the Jukes. As is typical

FIG. 134. A photograph suggesting the difference between insanity and feeble-mindedness. Altho feeble-mindedness and insanity are closely related, one can readily recognize the presence of an insane individual in a group of feeble-minded people. The young lady (age 21) whose face appears twice in the picture was seemingly normal until 17 years old when she became insane. Her father is very nervous and her mother died when insane. The colored woman, as well as the one to the right of her, present splendid examples of magocephalic feeble-mindedness.

of the average young man of to-day, Martin passed thru his wayward career, won the heart of a well-respected woman, and settled down. As a result of this "happy" union, a long line of offspring of normal and superior type was produced. With reference to the two families having the same father but different mothers, Goddard concludes: "The fact that descendants of both the normal and feeble-mindeded mother have been traced and studied in every conceivable environment and that the respective strains have always been true to type, tends to confirm the belief that heredity has been the determining factor in the formation of their respective characters."

When we come into a full realization of the fact that such degenerate families, many members of which may be closely or distantly related by illegitimate matings to the highest ranked citizens of the community; when we can count the cost in human suffering of the so-called "wild oats"; when we can feel the hopelessness of the struggling of the unfit, we will heed the magic pleading of the unborn: "*Refuse to give me birth or else let me be well born*" (Fig. 110, Ch. XXIV).

Regardless of the fact that we now recognize marked contrasts in all family differences, our forefathers expressed the inner feelings of the times by embodying in the Declaration of Independence, "All men are created equal," and that "life, liberty, and happiness" were the "inalienable rights" of every human being. How soothing this principle of human equality must be to the dreamer who hopes to reform mankind by his Utopian plans. When we look about us and see the depths to which some family strains have fallen we are prone to conclude that some men are born with terrible handicaps and that for them "the pursuit of happiness" is but a mere phantom (Fig. 134). If all men were created equal, the hopes of the eugenicists in the breeding of a superior race would come to naught. But since observations of such family histories as noted above do not support such antiquated views, we must face the facts and conclude that the success or failure of the future race depends largely upon whether or not the superior surpasses the inferior of the present race in productiveness. The problem confronted is twofold. In the first place the great prolificness of the socially undesirable classes must be overcome. This cannot be done by increasing the offspring of the superior. The latter is, within itself, a problem of great magnitude. The productiveness of the unfit must be curbed or there is grave danger of the future society being engulfed by degeneracy.

The problem, then, is one of eliminating the unfit by refusing them birth. In the second place the reproduction of the fit must be encouraged. The problem is not alone biologic in its aspect—it has its economic side as well. The fit may degenerate thru adverse economic conditions to the lowest level in the dregs of society. The biologist and the economist must work together in harmony if any lasting good is to be accomplished.

The present trend of social conditions is still somewhat discouraging—especially if viewed from a biologic standpoint. In our early considerations of the prodigality of nature (Chapter XI), it was found that superior numbers were a great factor in the perpetuation of any type of plant or animal life. In the case of the human race, it is well known that the inferior stock are reproducing their kind in much greater numbers than are the superior. This is largely due to the fact that the latter are attempting to conform to the economic demands of the present day while the former are prone to ignore these needs and be governed by their elemental instincts and emotions rather than by reason. The ambitious individual must spend years in preparation for whatever profession he hopes to enter. In this way, the offspring of the superior stock is reduced by late marriages. In many such cases the period of reproductiveness of the woman is so near an end that nature forbids more than one child. This fact suggests the desirability of the woman's being a number of years younger than her husband in order to more nearly equalize the period of reproductiveness of the two.

It is a deplorable fact that a large percentage of the most intellectual and superior women never marry. This is due, in part, perhaps, to the fact that the task of life preparation has displaced matrimony so long that the one great incentive—motherhood—is gone. Leonard Darwin, in an address to the International Eugenics Congress (Sept., 1921), emphasized the fact that "it is normally wrong to limit unduly the size of the family when parents are up to 'standard' in all respects."

Contrast, if you will, the low rate of reproduction of the superior classes in America with the overproduction of children by the inferior classes whose mental and moral standing are often nearer that of the brute than that of civilized man. These feeble-minded, vicious, and diseased individuals are competing with intellectual man for supremacy in the perpetuation of human characteristics. The ascent of man to the higher plane made possible by his superior intelligence may be entirely prevented by these degenerating influences. At the least, they present a handicap of no mean proportions.

The condition of society a few generations hence will determine which of the two, the good or the bad, will survive. However, at present, it seems as tho the inferior are by far surpassing the superior. For, it must be emphasized that society is so organized in America that those classes which pull down the standards of the human race have considerable advantages in reproduction over the intellectual classes. The "ne'er-do-wells" rush headlong into a passionate type of mating at an early age and proceed to degrade civilization with three or four times the number of children that are produced by the better classes. Kellicott reminds us that "one-fourth of the married population of the present generation produces one-half of the next generation," and, unfortunately, a large percentage of this one-fourth is of the lowest human type.

In view of the above facts, it must be concluded that a grave responsibility rests upon the eugenicists. If the race is to improve, some changes must be brought about by which the superior will be perpetuated to the exclusion of the inferior, or, at least, a more equal birth rate must be established between the two. This could be brought about largely by checking the birth rate in the inferior families and by encouraging earlier marriages among the superior in order to increase the number of healthy and normal children. The formulation of even a few theoretical suggestions relative to either of these methods is a very hazardous task, as the former class contends that the production of children is "a God-given right," the number to be limited only by chance. Many of the superior class feel that they are in a better position to judge the number of their offspring than the greatest eugenicist of the day—and rightly. When we are reminded that every country of the earth is rapidly becoming overpopulated, we are apt to direct the heaviest eugenic-artillery upon the overproduction of children by the inferior classes and content ourselves with the present numerical limitations of superior children—the present need being deemed human quality rather than human quantity. If quality is made the first consideration, quantity will take care of itself.

Few citizens realize the seriousness of the growing complexity of human society. Neither do the masses care to be reminded that the earth is becoming so densely populated that human catastrophes are inevitable if the present progress continues. This fact was brought directly to the author's attention when the editor of a certain church journal returned an article upon population with his regrets. Nevertheless, the time is not far distant when America will be overpopulated as are Europe, China, Japan and India. When the dark hour comes, the economic, social and moral conditions, unless properly directed now, will be no better than exist in these overpopulated countries of to-day. Americans, accustomed to extravagance and wasteful living, favored by Nature and provided with one of the richest garden-spots of the world, will find it humiliating, to say the least, when they are forced to a lower standard of living by the grim hand of necessity.

This fact can be more fully appreciated after reviewing the earth's population as a whole. Europe has little to offer as a relief for the suffering neighbors. During the war, Germany and Austria were able to survive without much outside relief, and it is no doubt true that with the strictest economy Europe can support herself. England was threatened with starvation when her foreign commerce was endangered by the submarine warfare. She is almost wholly dependent upon the outside world for subsistence. The peoples of Asia, being already crowded, are struggling for an existence. China, with one-fifth the population of the earth, has long since reached the limit of her capacity, and the annual death from starvation oftentimes reaches into the millions. India, with one-fifth the population of the earth, is but next door to starvation. Japan is struggling for an outlet for her thrifty, ambitious sons who are to-day cooped up on a few small islands, over sixty-five million on one hundred and seventy-five thousand square miles of territory, only a small part of which is tillable. The state of Texas contains two hundred sixty-five thousand, eight hundred ninety-six square miles,—nearly twice the area of Japan. Our greatest hopes must be placed in South America and Africa, although certain sections of these countries are already crowded.

If the population of South America and Africa increases as fast as that of North America, their citizens will be looking for an outlet before our grandchildren are gray. And the possibilities are that they will increase more rapidly than this, since there are now many more centers of emigration than there were during the days of our Pilgrim Fathers. Even to-day we marvel at the tremendous task Mother Earth faces when she undertakes to feed, clothe and shelter her 1,700 million (East) children. What hope have we for the future when every year adds 25 million more people to this great mass of struggling humanity. While we are rushing food, money, and clothing to the suffering famine-stricken Chinese, we are little mindful that almost 3,000 more names are added every *hour* to the birth registry of mankind than are erased by the hand of death.

East says, "have we realized, can we realize, that two Belgiums are added to the world's population each year and all must be fed, tho perhaps some need not be clothed."

Pearl has shown by various mathematical problems that the internal resources of the United States are inadequate to support twice as many citizens as we have to-day; and that the capacity will be reached in 180 years. When that time comes, the struggle for existence will be much keener than it is at present. Millions of the less fortunate will be forced to live a very simple life. Citizens with inadequate food, clothing, and shelter will be the rule rather than the exception as it is to-day. The ultimate end will be the elimination by famine and starvation of the less fortunate,—those who are now finding it difficult to provide for the necessities of life.

One who believes that only the fittest survive might become very optimistic and conclude that this intense struggle for existence will be a means by which the lower classes of mankind will be eliminated. In fact this would probably be the inevitable result were the various human agencies eliminated. But the intellectuality of man makes it impossible for this Biologic Principle of animal improvement to render much effect upon mankind.

With man, the scarcity of food is one of the principal factors in the reduction of the birth rate. On the other hand, the domestic animals mate and produce abundance of young regardless of whether the master's barns are full or empty. With man the possibilities of food, shelter and clothing do affect the number of the offspring.

However, this reduction of the birth rate does not come equally with all classes. The superior, being more prone to solve their problems by logical reasoning processes, are the first to reduce the family, while the inferior continue their usual rate of production regardless of any unfavorable circumstances that might arise. Unless conditions change, this factor will probably more than counterbalance the elimination of the unfit by starvation. So the net result would be *the elimination of the fit and the perpetuation of the unfit.*

Regardless of the fact that the earth is rapidly becoming overpopulated, and, moreover, that this crowded condition is tending toward a degenerated stock, we find the birth extremist pleading for the unborn. The following is a typical case:

"While the war was still raging, someone remarked: *'This world is no place for babies.'* How horribly true this remark! In Belgium the number of births fell off 350,000; in Serbia, 760,000; in Great Britain, 1,000,000; in France, 1,500,000; in Italy 1,500,000. It is estimated that more than 20 million babies, who under normal conditions would have been born in Europe, were denied existence.

"A generation hence, if not before then, the world will suffer by reason of those 20 million empty cradles."

A visit to the homes of some of the hereditary degenerate races of any community will convince one that there are thousands of American homes in which there is "*no place for babies*." In other words, every progressive social worker, biologist, or minister has long since been forced to admit that millions of children are coming into the world who should have remained unborn. Every intellectual man or woman who will become versed in the eugenic literature of the day will accept this statement as an axiomatic truth.

As for the world's *suffering* because 20 million children were not born, it would probably be of interest to note the position of the authoritative men of the U. S. on the subject of population. Pearl (*Harper's*, May, 1921) admits that "the proportion of deaths to births increased as long as the war continued;" however, this noted biometrician continues, "in spite of all of the havoc of war England's net population went right on increasing . . . In the U. S. the death-rate ratio was not affected at all by the war."

Even tho 9,829,000 [1] men were actually killed and perhaps many more died as an indirect result of the war, the net population of the world was but little affected. East says, "The tide of population is not kept back by the flimsy barrier of war, it is but baffled for the moment."

In view of the present complexity of the human society, it does not seem very pitiful that 20 million children were not

[1] Estimate of the Danish Research Society on the Social Results of the War.

FIG. 135. Four interesting bed cases, upper (age 10), microcephalic and a case of congenital syphilis (father paralytic). Hydrocephalic (age 8 and 11) middle; hydrocephalic (age 5) lower. "Happy" (center right) is the only one of the group that is responsive to any stimulus other than what we call extreme pain. Little does "Happy" realize that his mother is troubled with chronic chorea and delusional insanity. The head of the child in the lower picture measures 31 inches in circumference; body length 13 inches. The child is shown in its normal position, the distance between the back of the head and the hip being only three inches. All such bed cases must be fed either with a spoon or a tube. A number of cases are recorded which live in this pitiful condition for fifty or sixty years. Question: If you were one of these people, and should come to the realization of your condition for only ten minutes, what would you say to careless "civilized" man?

born. It *is* deplorable, however, that another 20 million which *were* born during the war, are now starving and filling the world's institutions for the physical and mental defectives. If it is true, as I have stated above, that the birth-rate decline first expresses itself with the superior human stock, then investigations will reveal the fact that the larger per cent of the 20 million children whose birth the war prevented would have been superior stock; and that the relative percentage of the births from the inferior stock is not materially reduced. To

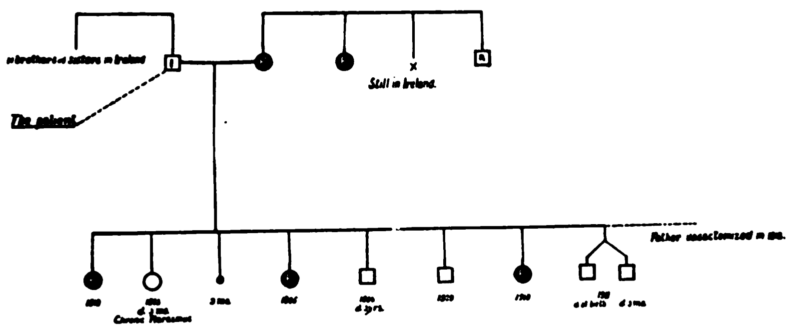

Fig. 136. The periodically insane man (the patient) married a feeble-minded woman and produced nine offspring within eleven years, only one of whom showed any indication of normality. The sterilization of the father in 1912 prevented continuance of this low grade strain. (From Eugenic Record Office.)

this extent, only, will the "world suffer by reason of those twenty million empty cradles."

Among the many methods which have been advanced with a view to reducing the birth rate of the inferior, colonization, segregation, sterilization, and restriction of marriage laws have all had an abundance of supporters. Each one of these is very effective indeed, but only to a limited extent. To cite such a race of degenerates as the Cretins of northern Italy should suffice to establish the impracticability of colonizing the degenerates, as the custom of breeding *inter se* unites the inferior qualities of each individual into a more degenerate offspring. The level of the entire colony is lowered more and more until it is thrown entirely upon the mercy of the state for sustenance. Under the most restricted rules of segregation, even when the two sexes are separated, there still remains the possibility of degenerate illegitimate children appearing.

One sane method by which offspring may be prevented is that of sterilization—at present a very simple and harmless procedure (Fig. 136). Many states have already provided for a competent board of examiners composed of physicians, psychologists, and eugenicists who are duly authorized to render sterile those inmates of asylums, penitentiaries, and other institutions, who are deemed unfit to leave offspring. Unfortunately, public opinion, even in those states where adequate laws have been passed, opposes this procedure to such an extent that the sterilization boards are not free to perform their full duty. No great results can be hoped for until the public is in greater harmony with this particular method of race improvement. Even then, sterilization will solve only a minor part of the problem, as only the extreme cases can be reached. No one will be willing to condemn the questionable cases. Attention has been called (Chapter XXIV) to that great group of individuals who are apparently normal but who possess "impure" germ cells and thus produce a part or all defective offspring, depending upon the type of individual with which they mate. Since these people, in many cases, are the leaders of the community, they need never fear the sterilization laws even though their children may be, under certain conditions of mating, as low as those of the lowest degenerates in the charitable institutions (Fig. 137).

Informing the Public.—After considering various methods of race improvement, we readily realize that none are effective unless in accord with public opinion. An eugenic education for the public at large is, therefore, the main issue of the day. This method of race improvement has been very slow, but, with the assistance of the intellectual classes and with the present awakening, considerable progress should be made within the next few years. In our economic world, we slumbered hundreds of years before we became dissatisfied with the old methods of doing things. Then, we were content to travel over the great prairies in oxcarts. Now, the journey is made in the air within a few hours. Then, nation communicated with nation by means of slow-going sailboats. Now, messages are flashed by wireless. In like manner, let us hope that within a very few years it can be said that the American people, who once slumbered in eugenic indifference and who were unconscious of the cries of the unborn, are now awakened to their human responsibilities. If such optimistic dreams could be realized, the selection of a mate and the business of reproduction might come to be considered as seriously as is stock breeding at the present time. "Love at first sight," without a consideration of the family from which the individual came, would then be a thing of the past.

After a life mate had been selected, children would be brought into the world in accordance with definite plans rather than by mere chance, if such things as noted above could be brought about. At present, even with the mediocre, definite plans are made for the purchase of a horse or the movement to a new location, and these plans are altered in accordance with various unexpected circumstances. However, in the matter of reproduction there is no thought of the future—no plans are made. The production of children only through obedience to the animal instinct to mate has not only populated the land with hordes of unfit individuals but it has filled the cemeteries with the graves of the victims of infant mortality. It has also caused millions of miscarriages, stillbirths, and a large proportion of the misery of mankind. This situation will become apparent by asking a few grandmothers, who boast of the large number of children which they have produced, how many died before the age of six. It is very common to find that from thirty to fifty per cent of the children of such families did not survive in the struggle for existence. The writer overheard one grandmother lamenting the fact that one of her daughters was falling short of her "sacred duty" by producing only two children. When this lady was reminded that another member of the family was the mother of only three children she replied that it was not this young mother's fault as she had given birth to six children but that three had died at birth or within a few weeks thereafter. It was upon such a record that the grandmother herself felt excused, as she was

FIG. 137. Living Death. For forty-one years this strange knot of flesh has been under constant parental and State care. With little response to external conditions she lies for hours in this knotted position, with her head suspended above the pillow. This is a very pitiful case of so-called "birth-mark." The mother, by worrying over certain home conditions is supposed to have "marked" the mentality of her child. What place has Eugenics in America as long as such superstitions are held?

the mother of thirteen children—six having died in infancy. The question then arose, would it not be better to produce from two to three or four children in accordance with systematic plans, making provision for the future of each, rather than to do your *not* "sacred duty" but "passionate duty" and give to the world six or eight unfortunates and allow half of them to die in infancy through lack of proper care. The answer to such vital questions may be found through a comparison with the plant and animal world. A good breed of cattle or of hogs, well planned and cared for, is a safer investment than is twice or three times the same number of scrubs. With all progressive agriculturists, *extensive* farming has long since been replaced by *intensive* methods. Why then can we not conclude that it is *quality* and not *quantity* that counts. If the human race is to continue its march of progress to the final goal, it is extremely vital that the fit shall become the progenitors of the characteristics of mankind to the utter exclusion of the unfit.

Large families have many disadvantages. This is true from the biologic as well as from the economic standpoint. The economic disadvantage alone should be a deciding factor with those who are not really in a position to afford a large family. However, it is not so. It is the very class which can least afford large families that most often have them. Children are brought into the world and allowed to grow up like weeds. These same families could be a credit to themselves and to the community if they contained fewer members better cared for and better raised. Moreover, where a large number of children are produced, there is more likelihood of abnormal characteristics appearing. In most cases, these characteristics tend away from the normal in the negative direction. Not only the hereditary side of the question but also the environmental side must be considered. Conditions are more favorable in large families than in small ones, especially when the economic pressure is heavy, for children to became wayward and develop abnormal traits. Thus we find that a large proportion of our criminal class, our paupers, and degenerates in general, have come to be such through improper paternal care and supervision.

Eugenics and Religion.—The above line of thought is presented with due regard for the old notion that a certain relation exists between marriage, birth, and religion. Although many creeds still contend that "marriages are made in heaven," we have long since learned that the children must be reared here on earth. And, furthermore, an eugenic study of some of these so-called "heavenly" marriages indicates everything but a divine mating. Indeed, every marriage should be considered sacred sufficiently to cause those involved to have a feeling of *responsibility*. Without a feeling of responsibility, marriage becomes a farce and the production of children the outcome of irresponsible indulgence. It is easily seen that such conditions do not tend to nurture the best standards of child care. The production of children should be so much involved in religious principles that the minimum number of unfit will be produced; for what need has the state, the church, or the home for the poor unfortunate, degenerate, feeble-minded, or syphilitic child? Each of these great institutions—state, church, and home, is evolving to meet the changing economic needs. Indeed, "religion itself evolves, and any religion which does not embrace *eugenics* will embrace death."

Religion should not only embrace eugenics but it should involve the entire realm of human knowledge including evolution and genetics as a whole. Only a few years back, evolution and religion stood far apart as extreme and bitter antagonists, but to-day we find that the underlying principles of each have been so broadened that they are now not only tangent but so interlaced that the one acts as a strong support for the other. Yesterday, the ministers of every civilized land viewed evolution as a bitter foe while the scientists were thought to be atheists. To-day, the most learned religious leaders are seeing religion reflected in evolution, and the evolutionists, through their interpretation of the natural laws, are becoming more ardent believers in a Superior Ruler of the Universe. As science and religion progress the two will be more firmly *rooted* together.

"We must prove that we are under the guidance of a noble ideal. We of this generation are responsible for the production of the next generation and, therefore, of all mankind in the future; and all in whom this sense of racial responsibility acts as a deep-seated sentiment, greatly affecting their action and their policy, are in truth guided by the eugenic ideal. The belief that man has been slowly developed from some apelike progenitor came towards the close of the last century to be nearly universally held by thoughtful persons; *this belief gave rise to a new hope that this upward march of mankind might be continued in the future; and out of this new hope sprang the eugenic ideal.* This growing understanding of the past history of the world led us to see that, if we are to imitate Nature in her methods, we must be content to advance by means of a long succession of small steps; just as the rain falling in drops has slowly carved out mighty valleys in the hardest rocks. Without constructing wild Utopias, we must be content if some little racial progress can be assured as each generation succeeds another; for to work in this spirit is to work in harmony with the knowledge which gave birth to the eugenic ideal. *Progress on eugenic lines will make mankind become continually nobler, happier and healthier;* whilst those who imagine that our sole aim is to make man a stronger animal or a better beast of burden are utterly ignorant of the meaning of the eugenic ideal" (Leonard Darwin, *Science*, Oct. 7, 1921).

The idea of religious principles being involved in evolution has been accepted by some of the world's greatest scientific workers. Dana, an authority on geologic evolution, says, "The intervention of a Power above nature was at the basis of man's development." He believed that "nature exists through the will and ever exacting power of the Divine Being and that all its great truths, its beauties and its harmonies are manifestations of His wisdom and power." Wallace, the greatest exponent of Darwinian Evolution, states his religious convictions thus: "We find that Darwinism does *not* oppose but lends a decided support to religion, it teaches us that we possess intellectual and moral faculties which could not have been developed but for an unseen Universe of Spirit." Such present-day writers as Popenoe and Johnson are fully convinced that "Man is the only animal with a religion." The distinguished American biologist, David Starr Jordan, accepts the saying of the old Chinese sage, "He cannot be concealed: He will appear without showing Himself, effect renovation without moving, and create perfection without acting. It is a law of heaven and earth, whose way is solid, substantial, vast and unchanging." After years of investigations into the principles of evolution and considering the convictions of the greatest scientific leaders, the writer is convinced that "evolution in a last analysis is *the shining into Finite forms of Infinite Light*."

When the entire human race has arisen to the call of nature and her Director, when man realizes the possibilities of eugenics, when the Laws of Life are properly directed, when evolution and religion have swept on and on hand in hand for a million years, the Maker of the Universe can truly look upon a race "moulded in His own image." Then and only then will the "super-man" exist outside the realms of present childish human dreams. Then and only then will the optimistic song of the poet become a reality.

"What a piece of work is man!
How noble in reason!
How infinite in faculty!
In form and moving how express and admirable!
In action how like an angel!
In apprehension how like a God!"

THE LAST LECTURE

"Our course is run, our harvest garnered in,
And taking stock of what we have, we note how life,
This strange, mysterious life which now we hold and now eludes our grasp,
Is governed still by natural law, and its events
Tread on each other's heels, each one compelled to follow where the first has led.

Noting all this, and judging by the past,
We form our plans, until we know at last
The treasure in the future's lap.

"The man, the plant, the beast, must all obey this law,
Since in the early dawn of this old world
The law was given, and the stuff was made
Which still alone can hold the breath of life:
Whereby we know that grass and man are kin,
The bond a common substance which within
Controls their growth.

"Can we know all? Nay, but the major part
Of all that is must still elude our grasp,
For life transcends itself, and slowly noting what it is,
Gathers but fragments from the stream of time.
Thus what we teach is only partly true.
Not knowing all, we act as if we knew,
Compelled to act or die.

"Yet as we grow in wisdom and in skill
The upward path is steeper and each step
Comes nigher unto heaven, piercing the clouds
Which heretofore have hid the stars from view.
The new-gained knowledge seems to fill the air,
It seems to us the soul of truth is there.
Our quest is won.

"Bold climber, all that thou hast won
Lies still in shadow of the peaks above;
Yet in the morning hours the sun
Rewards thy work of love,
Resting a moment on thy lesser height,
Piercing the vault with rays too bright to face,
Strengthens thy soul and gives thee ample might
To serve thy human race."

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